

NASA-CR-166,029

NASA Contractor Report 166029

COMPUTER PROGRAM FOR POST-FLIGHT EVALUATION OF A
LAUNCH VEHICLE UPPER-STAGE ON-OFF REACTION
CONTROL SYSTEM

R. N. KNAUBER

NASA-CR-166029
19860004452

VOUGHT CORPORATION
P. O. Box 225907
Dallas, Texas 75265

NASA Contract NAS1-15000
November 1982



NF02229



National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

~~FOR EARLY DOMESTIC DISSEMINATION~~
Because of its significant early commercial potential, this information, which has been developed under a U.S. Government program, is being disseminated within the United States in advance of general publication. This information may be duplicated and used by the recipient with the express limitation that it not be published. Release of this information to other domestic parties by the recipient shall be made subject to these limitations.
Foreign release may be made only with prior NASA approval and appropriate export licenses. This legend shall be marked on any reproduction of this information in whole or in part.
Review for general release November 30, 1985

LIBRARY COPY

DEC 1 1982

LANGLEY RESEARCH CENTER
LIBRARY, NASA
HAMPTON, VIRGINIA

COMPUTER PROGRAM FOR POST-FLIGHT EVALUATION OF A LAUNCH VEHICLE
UPPER STAGE ON-OFF REACTION CONTROL SYSTEM

SUMMARY

This report describes a FORTRAN IV coded computer program for post-flight evaluation of a launch vehicle upper stage ON-OFF reaction control system. Aerodynamic and thrust misalignment disturbances are computed as well as the total disturbing moments in pitch, yaw, and roll. Effective thrust misalignment angle time histories of the rocket booster motor are calculated. Disturbing moments are integrated and used to estimate the required control system total impulse. Effective control system specific impulse is computed for the boost and coast phases using measured control fuel useage. This method has been used for more than fifteen years for analyzing the NASA Scout Launch Vehicle second and third stage reaction control system performance.

The computer program is set up in FORTRAN IV for a CDC CYBER 175 system. With slight modification it can be used on other machines having a FORTRAN compiler. The program has optional CALCOMP plotting output. With this option the program requires 19K words of memory and has 786 cards. Running time on a CDC CYBER 175 system is less than three (3) seconds for a typical problem.

This Page Intentionally Left Blank

TABLE OF CONTENTS

Page

SUMMARY	1
TABLE OF CONTENTS	iii
LIST OF ILLUSTRATIONS	iv
LIST OF SYMBOLS	v
1.0 INTRODUCTION	1
2.0 METHODOLOGY	2
2.1 Assumptions	2
2.2 Equations	3
2.2.1 Disturbing Moments and Thrust Misalignment	3
2.2.2 Total Impulse Expended	5
2.2.3 Control Fuel Usage	5
2.2.4 Angular Accelerations	7
3.0 PROGRAM DESCRIPTION	
3.1 General	8
3.2 Program Flow	8
3.3 Subroutine Description	8
3.4 Input Data Description	11
3.4.1 Options and Title	11
3.4.2 Constants	12
3.4.3 Boost Phase Tables	13
3.4.4 Boost Phase Angular Accelerations	15
3.4.5 Boost Phase Rate Slopes	16
3.4.6 Incremental Impulse	17
3.4.7 Control Fuel	18
3.4.8 Coast Phase Constants	19
3.4.9 CALCOMP Plot Variables	19
3.5 Output Data Description	20
3.5.1 Boost Phase - Pitch	20
3.5.2 Boost Phase - Yaw	21
3.5.3 Boost Phase - Roll	22
3.5.4 Boost Phase - System Variables	23
3.5.5 Coast Phase	23
3.5.6 CALCOMP Plots	24
Appendix A -	A-1

LIST OF ILLUSTRATIONS

<u>Figure No.</u>	<u>Descriptions</u>	<u>Page</u>
1	Sign Convention	25
2	Disturbed and Undisturbed Motion	26
3	Typical Rate Time Histories	27
4	Flow Chart of UPSTAG	28
5	Sample Problem Input Data	35
6	Sample Problem Printed Output Data	38
7	Sample Problem CALCOMP Plots	43

LIST OF SYMBOLS

	<u>Units</u>
a_3	cubic coefficient in aerodynamic normal force coefficient versus angle of attack expression.....1/deg ³
C_N	aerodynamic normal force coefficient..... —
$C_{N\alpha}$	aerodynamic normal force coefficient slope at zero angle of attack.....1/deg
C_{reg}	control fuel system regulated gas pressurization compressibility factor..... —
C_g	control fuel system unregulated gas pressurization compressibility factor..... —
F_c	control motor force.....lbs
I_{sp}	control fuel specific impulse.....lb -sec/lb _m
I_T	control system total impulse.....lb _f -sec
I_x	roll moment of inertia.....slug-ft ²
I_y	pitch or yaw moment of inertia.....slug-ft ²
K_t	rate trace paper speed.....in/sec
K_p	rate trace scale factor.....deg/sec/in
L	roll moment.....ft-lbs
l_c	pitch or yaw control moment arm.....ft
l_r	effective thrust misalignment moment arm.....ft
M	pitching moment.....ft-lbs
N	yawing moment.....ft-lbs
P	pressure.....psia
Q	dynamic pressure.....lbs/ft ²
R_c	roll control moment arm.....ft
S	aerodynamic reference area.....ft ²
T	booster thrust.....lbs

LIST OF SYMBOLS (continued)

T_g	temperature of pressurizing gas.....°R
V_g	unregulated pressurizing gas volume.....in ³
W_c	control fuel weight.....lbs
W_p	rocket booster propellant remaining.....lbs
x	body station.....inches
z_c	location of pitch or yaw control motors from centerline.....inches

Greek Letters

α	angle of attack.....deg
β	angle of sideslip.....deg
η	total aerodynamic angle.....deg
θ	pitch attitude.....deg
ϵ_r	effective booster thrust misalignment.....deg
λ_c	pitch and yaw control motor cant angle.....deg
λ_r	orientation angle of thrust misalignment.....deg
$\lambda_\theta, \lambda_\psi, \lambda_\phi$	rate trace slopes.....deg
ρ_L	weight density of control liquid fuel.....lbs/in ³
ϕ	roll attitude.....deg
ψ	yaw attitude.....deg

Prefix

∂	derivative or differential
Δ	incremental value
Σ	prefix summation sign

Subscripts

aero	aerodynamic
c	control

Subscripts (continued)

cg	center of mass
cons	consumed
cp	aerodynamic center
d	disturbance
g	gas
L	liquid
N	normal force
O	initial value
p	pitch
R	roll
reg	regulated gas
rem	remaining
T	total
y	yaw
r	booster thrust

Special Notation

$\int dt$	integral with respect to time
.	dots above a variable denote derivative with respect to time

1.0 INTRODUCTION

Post-flight analysis of a reaction controlled launch vehicle upper stage should include computation of the disturbing pitch, yaw, and roll moments, control fuel consumption, estimated control fuel specific impulse, as well as other performance measures. The method presented herein, provides a useful tool to aid in these tasks for an ON-OFF reaction controlled vehicle. It is a straightforward deterministic approach based on uncoupled rigid body equations of motion. Impulse and control fuel useage is based on integration of the absolute value of average duty cycles required to balance disturbing moments and optional inputs for additional impulse such as used during limit cycle operation. Being straightforward and simple this important evaluation method is sometimes overlooked in post-flight evaluation of reaction-control systems.

The method has been used for more than fifteen years for evaluating the ON-OFF hydrogen peroxide reaction control systems on the second and third stages of the NASA SCOUT (SCientific Orbital Utility Test) Vehicle. Use of this method has led to an accurate data bank on the booster rocket motors thrust misalignment and roll torque characteristics and control system specific impulse deviations. It has also been useful in helping diagnose rocket motor failures.

Input data required includes dynamic pressure, angles of attack and sideslip, angular accelerations or angular rate trace slopes, booster thrust and weight time histories, mass properties, control fuel or pressurization variables, and vehicle control moment arms. Optional input includes incremental rates at control motor firings and/or incremental impulse.

Methodology and a detailed computer program description is presented herein. Details of the computer program including a sample problem and detailed input and output descriptions are presented in Section 3. A complete FORTRAN listing is presented in Appendix A.

2.0 METHODOLOGY

This section presents the methodology and equations which can be used to compute pitch, yaw and roll disturbing moments, effective thrust misalignment, total impulse expended by the control system, control fuel consumption and effective overall control system specific impulse. Knowledge of vehicle angular rate time histories and control motor firings from telemetry data is required. Booster thrust, dynamic pressure, angles of attack and sideslip, are also required. If the ON-OFF control system is a regulated pressure system an option of computing fuel useage is included based on measured pressure and temperature of the unregulated pressure supply.

2.1 Assumptions

Major assumptions and approximations made in the method are:

- . non-spinning three-axes stabilized vehicle,
- . ON-OFF reaction control motors which are off sufficiently long to define angular accelerations about each axis,
- . aerodynamic and mass properties symmetry in pitch and yaw,
- . no gyroscopic cross-coupling terms,
- . aerodynamic coefficients are non-linear with angle of attack and can be described by a cubic for normal force coefficient and a linear variation of aerodynamic center with absolute value of angle of attack,
- . control impulse expended assumes balance of disturbing moments plus an additional impulse supplied as input,
- . control impulse calculations assume independence of pitch, yaw, and roll control motors (no mixing of pitch-roll or yaw-roll, etc.),
- . optional calculation of control fuel useage from unregulated pressure and temperature assumes nitrogen pressure regulated system without venting and non-varying temperature on regulated side,
- . no rocket motor jet damping in pitch, yaw, and roll,
- . no aerodynamic damping

2.2 Equations

2.2.1 Disturbing Moments and Thrust Misalignment

The angular equations of motion in pitch, yaw and roll based on the previously mentioned assumptions are (see Figure 1 for sign conventions):

$$(2-1) \quad I_y \ddot{\theta} = 57.3 \sum M = 57.3 [M_C + M_r + M_{aero}]$$

$$(2-2) \quad I_y \ddot{\psi} = 57.3 \sum N = 57.3 [N_C + N_r + N_{aero}]$$

$$(2-3) \quad I_x \ddot{\phi} = 57.3 \sum L = 57.3 [L_C + L_D]$$

Control moments are:

$$(2-4) \quad M_C = -F_{Cp} l_C \quad (\text{ft-lbs})$$

$$(2-5) \quad N_C = -F_{Cy} l_C \quad (\text{ft-lbs})$$

$$(2-6) \quad L_C = -2 F_{CR} R_C \quad (\text{ft-lbs})$$

where the control moment arm is,

$$(2-7) \quad l_C = [(x_C - x_{cg}) \cos \lambda_C + z_C \sin \lambda_C] / 12 \quad (\text{ft})$$

Booster induced moments which are produced by all sources (i.e., angular, offset, swirl, jet damping, etc.) are all lumped into an effective thrust misalignment angle in the pitch and yaw planes.

$$(2-8) \quad M_r = T \epsilon_{rp} l_r / 57.3 \quad (\text{ft-lbs})$$

$$(2-9) \quad N_r = T \epsilon_{ry} l_r / 57.3 \quad (\text{ft-lbs})$$

where the thrust side force is assumed to act at the nozzle throat,

$$(2-10) \quad l_r = (x_r - x_{cg}) / 12 \quad (\text{ft})$$

aerodynamic moments are,

$$(2-11) \quad M_{aero} = C_N S Q (x_{cg} - x_{cp}) \tan \alpha / 12 \tan \eta \quad (\text{ft-lbs})$$

$$(2-12) \quad N_{aero} = -C_N S Q (x_{cg} - x_{cp}) \tan \beta / 12 \tan \eta \quad (\text{ft-lbs})$$

total aerodynamic angle (η) is,

$$(2-13) \quad \eta = \tan^{-1} \sqrt{\tan^2 \alpha + \tan^2 \beta}$$

aerodynamic normal force coefficient is a cubic function of ' η ',

$$(2-14) \quad C_N = C_{N\alpha} \eta + a_3 \eta^3$$

and aerodynamic center is,

$$(2-15) \quad x_{cp} = x_{cp_0} + \frac{\partial x_{cp}}{\partial \alpha} |\eta| \quad \text{inches}$$

Total disturbing moments are computed from equations 2-1, 2-2, and 2-3 when the control motors are off, i.e.,

$$(2-16) \quad M_D = I_y \ddot{\theta} / 57.3 \quad (\text{ft-lbs})$$

$$(2-17) \quad N_D = I_y \ddot{\psi} / 57.3 \quad (\text{ft-lbs})$$

$$(2-18) \quad L_D = I_x \ddot{\phi} / 57.3 \quad (\text{ft-lbs})$$

An effective moment due to the rocket booster is,

$$(2-19) \quad M_r = M_D - M_{aero} \quad (\text{ft-lbs})$$

$$(2-20) \quad N_r = N_D - N_{aero} \quad (\text{ft-lbs})$$

An effective thrust misalignment can then be computed from equations (2-8), (2-9), and (2-16) through (2-20) for periods when the control motors are off. Pitch, yaw and total effective thrust misalignment is,

$$(2-21) \quad \epsilon_{rp} = [I_y \ddot{\theta} - 57.3 M_{aero}] / T l_r \quad (\text{degrees})$$

$$(2-22) \quad \epsilon_{ry} = [I_y \ddot{\psi} - 57.3 N_{aero}] / T l_r \quad (\text{degrees})$$

$$(2-23) \quad \epsilon_r = \sqrt{\epsilon_{rp}^2 + \epsilon_{ry}^2} \quad (\text{degrees})$$

Total thrust misalignment angle and orientation angle (λ_r) is shown in Figure 1.

$$(2-24) \quad \lambda_r = \tan^{-1} (\epsilon_{ry} / \epsilon_{rp})$$

2.2.2 Total Impulse Expended

Total impulse expended by the control system is the integral of the absolute value of thrust-time histories of each control motor.

$$(2-25) \quad I_T = \sum \int |F_i| dt \quad ; \quad i = 1, 2, 3, \dots, n \quad \text{motors}$$

This information is not usually available. Estimation of this from motor commands and preflight measured thrust levels is often inaccurate when short pulse widths are commanded. During a boost phase the disturbing torques are generally large enough for the control system to operate on one side of the deadband resulting in a long period of single direction control motor pulsing (Figure 2). When this occurs the average angular impulse expended by the pitch yaw and roll control motors balances that produced by the disturbances. The linear impulse is,

$$(2-26) \quad I_T = \int \left[|M_D/l_c| + |N_D/l_c| + |L_D/R_c| \right] dt + \Delta I_T$$

where ΔI_T is an additional impulse,

When the control system deadband is crossed opposite motors fire (Figure 2). If this occurs the impulse expended includes the balance of disturbances plus the balancing of the opposite motor plus the impulse expended by the opposite motor. For this reason the program includes an input table of an "additional" impulse (ΔI) time history which can be estimated by other means such as angular rate changes and measured motor pulse widths.

An option for computing the impulse from supplied changes in pitch, yaw and roll rates is available to cover periods of no disturbance such a limit cycle operation during a coast period. A typical rate trace is presented in Figure 3. The linear impulse required to produce the motion is,

$$(2-27) \quad \Delta I_T = \sum \left[|I_y \Delta \dot{\theta} / 57.3 \, l_c| + |I_y \Delta \dot{\psi} / 57.3 \, l_c| + |I_x \Delta \dot{\phi} / 57.3 R_c| \right]$$

With this option the absolute values of incremental pitch, yaw and roll rates must be supplied as a time history as described in the input data description (paragraph 3.4).

2.2.3 Control Fuel Usage

Measured control fuel usage can be input directly to the program to be used to compute an effective specific impulse.

$$(2-28) \quad I_{sp} = I_T / W_c \quad (lb_f\text{-sec}/lb_m)$$

This is computed as a running time history during the boost and coast phases.

If a closed pressure regulated liquid monopropellant control system is used there is an option to compute the liquid expelled from measured unregulated pressure and temperature. The following assumptions are made:

- total mass of pressurizing gas does not change
- regulated side gas pressure is the same temperature as the unregulated side
- liquid monopropellant density is constant
- the compressibility factor of the gas on the regulated side does not change

The amount of propellant expended is:

$$(2-29) \quad \Delta W_c = \frac{\rho_L C_{reg} V_g}{P_{reg}} \left\{ \frac{P_{g0} T_g}{C_{g0} T_{g0}} - \frac{P_g}{C_g} \right\} + \rho_L \Delta V_g \left\{ \frac{T_g}{T_{g0}} - 1 \right\}$$

where,

- ρ_L - weight density of the liquid fuel (lbs/in³)
- C_{reg} - compressibility factor of the regulated side gas pressure
- V_g - unregulated side pressurizing gas volume (in³)
- P_{reg} - regulated side gas pressure (psia)
- P_g - unregulated side gas pressure (psia)
- C_g - unregulated gas compressibility factor
- T_g - unregulated gas temperature (°R)
- ΔV_g - initial volume of gas on the regulated side (in³)

The zero subscript denotes values at the start of operation when a known quantity of fuel is in the tanks such as at initial operation.

The computer program includes a short subroutine (C) which computes the compressibility factor for dry diatomic nitrogen based on a curve fit. The curve fit is accurate for pressures in the range of 400 to 3000 psia and temperatures between 50 and 100 degrees Fahrenheit. The curve fit is,

$$(2-30) \quad C_g = 0.9977 + 1.657738 \times 10^{-5}(P_g - 1400) + 1.264881 \times 10^{-8}(P_g - 1400)^2 + 4.5833 \times 10^{-4}(T_g - 522)^2$$

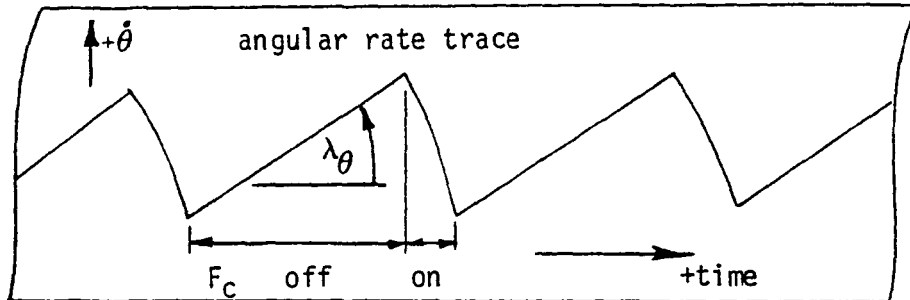
Control fuel remaining is the initial value minus that consumed,

$$(2-31) \quad W_{c_{rem}} = W_{c0} - \Delta W_c \quad (\text{lbs})$$

A time history comparison of the control fuel usage computed from measurements with that based on calculated total impulse and effective average specific impulse is output by the program.

2.2.4 Angular Accelerations

Angular accelerations between control motor firings are used to compute the disturbing moments (equations 2-16 through 2-18). An optional input includes the slope and scale factors from a plotted time history or oscillograph record as shown in the sketch below.



The angular acceleration is computed as,

$$(2-32) \quad \ddot{\theta} = K_t K_p \tan \lambda_{\theta} \quad (\text{deg/sec})$$

where,

K_t is the paper speed in length units per second.

K_p is the rate scale factor in degrees per second per length unit.

λ_{θ} is the slope of the rate trace in degrees.

3.0 PROGRAM DESCRIPTION

3.1 General

This computer program is programmed in FORTRAN IV for a CDC CYBER 175 system. The coding is compatible with ANSI standards. It is arranged to operate with standard card input and line printer output. Optional CALCOMP plotting is based on standard CALCOMP plotters and software.

A main routine (UPSTAG) and four subroutines require approximately 19K words of computer memory. All output is stored in array variables to facilitate a well formatted print and CALCOMP plot output format.

Program flow and user instructions are presented in the following paragraphs. Input and output of a sample problem is illustrated along with the detailed descriptions.

3.2 Program Flow

Program flow is straightforward in five basic parts:

- . input data
- . calculation of boost phase disturbances and impulse
- . calculation of coast phase variables
- . output data on line printer
- . optional CALCOMP plots

A flow chart of the main routine (UPSTAG) is presented in Figure 4. A complete listing of the FORTRAN program and subroutines other than the standard CALCOMP library subroutines are presented in Appendix A.

Descriptions of the four subroutines are presented in the following paragraphs.

3.3 Subroutine Description

Four subroutines are used to support the UPSTAG main program; C, CURVE, DASH, and TBLU. A brief description of each is presented below.

C

This short subroutine computes the compressibility factor for dry diatomic nitrogen by a curve fit over the pressure range of 400 to 3000 psia and a temperature range of 50 to 100 degrees Fahrenheit. The call statement is,

CALL C(P, T, CR)

where,

P is the input nitrogen pressure (psia)
T is the input nitrogen temperature (degrees Rankine)
CR is the output compressibility factor

CURVE

This subroutine is used to set up the sequence of CALCOMP plots for pitch, yaw, and roll disturbing moments and the effective thrust misalignments. Plots are set up for a 20 x 20 divisions per inch graph paper having a grid size of 10 x 7 1/2 inches (see the output data description in this section for a sample plot output). The data to be plotted is passed to this subroutine via common in arrays PVAR, YVAR, RVAR, and TVAR. Solid dashed and dash-dot line plots are accomplished by the subroutine DASH. The call statement is,

CALL CURVE (NP, NQ, IROLL, NTITLE, DYP, DYR, DYET, DX)

where,

NP input number of time points in the arrays to be plotted
NQ input controls
 NQ = 0 if aerodynamic moments are zero only the total
 disturbing moments are plotted
 NQ = 1 total disturbing moments in addition to aerodynamic
 and thrust misalignment moments are plotted
IROLL input control integer
 IROLL = 0 roll disturbing moment not plotted
 IROLL = 1 roll disturbing moment is plotted
NTITLE input title description of 80 characters with eight (8)
 'ten-letter' words
DYP input ordinate scale factor for the pitch and yaw moments
 (ft-lbs per inch).
DYR input ordinate scale factor for the roll moment (ft-lbs per
 inch)
DYET input ordinate scale factor for thrust misalignment (degrees
 per inch)
DT input abscissa scale factor for time (seconds per inch)

Note that care must be taken in selecting scale factors so that plotted data falls on grid. Limiting of the plotted data is automatically invoked in CURVE through the call statements to DASH.

DASH

This subroutine plots a curve on a CALCOMP plotter for a set of ordinates and abscissas. The style and type of line drawn is selected by the user. Note that the CALCOMP plot is specified in inches; plotting on metric paper requires appropriate scaling change before entering this subroutine.







The call statement is,

CALL DASH (X, Y, NP, Z1, Z2, SPACE, XSCALE, YSCALE, LSymb, XLIM, YLIM)

where,

X - input array of abscissa values
Y - input array of ordinate values
NP - number of points in X and Y to be plotted
Z1 - for dashed-dot lines this is length of long line measured
 in inches (see sketch below)
Z2 - for dashed-dot lines this is length of short line measured
 in inches (see sketch)
SPACE - for dashed style lines this is the length of the space between
 lines measured in inches.
 SPACE = 0 gives a solid line plot
 SPACE = negative gives special CALCOMP symbols at each point
XSCALE - abscissa plot scale factor (units per inch)
YSCALE - ordinate plot scale factor (units per inch)
LSymb - special CALCOMP symbol code number used if SPACE is negative
 (see code below)
 - (+) LSymb gives straight solid lines between symbol points
 - (-) LSymb gives only symbols at each point without lines
XLIM - plot limiting of the abscissa (inches) points out of range,
 range will appear at this limit
YLIM - plot range of ordinate (inches)

For ease in use, the following styles are typically possible,

LINE	TYPE	Z1	Z2	SPACE	LSymb
	Solid	--	--	0.	0.
	Dashed	0.25	0.25	0.10	0.
	Dashed	0.07	0.07	0.07	0.
	Dashed Dot	0.5	0.03	0.07	0.
	Symbols	--	--	-0.1	+2
	Symbols (no line)	--	--	-0.1	-2

TBLU

This is a single table lookup subroutine. It is based on linear interpolation between points for a single array having alternating values of abscissas and ordinates. The abscissas must be in ascending order.

The call to this subroutine is:

CALL TBLU (NT, Y, X, T, M)

NT - number of values in table 'T' including abscissas and ordinates.
Y - is the ordinate to be found.
X - is the given abscissa.
T - is the table of alternating abscissas and ordinates.
M - is the table locator to begin the table search. M must be an integer value from 1 to NT. This index is changed by the subroutine to the location found in the lookup.

3.4 Input Data Description

Input data descriptions are presented in the following subparagraphs. A sample problem input data listing is presented in Figure 5 for reference. The input data can be separated into the following groups:

- 1) option control card and title
- 2) constants
- 3) trajectory and vehicle characteristics tables
- 4) angular accelerations (not shown in Figure 5)
- 5) rate trace scale factors and slopes
- 6) additional impulse table and incremental rates
- 7) control fuel
- 8) coast phase only constants (not shown in Figure 5)
- 9) CALCOMP plot variables

3.4.1 Options and Title

The first card of input contains six integer control constants for the run. These are input in fields of five (5) columns. The number must be right justified. The input format is (10I5).

<u>FORTRAN</u> <u>NAME</u>	<u>COLUMN</u>	<u>DESCRIPTION</u>
IOPT1	5	option for input of pitch, yaw, and roll disturbing accelerations IOPT1 = 0 input angular acceleration tables IOPT1 = 1 input angular rate trace slopes and scale factors
IOPT2	10	option for input of control fuel useage IOPT2 = 0 read in table of fuel remaining time history IOPT1 = 1 read constants, pressure and temperature time histories and compute control fuel useage

<u>FORTTRAN</u> <u>NAME</u>	<u>COLUMN</u>	<u>DESCRIPTION</u>
IOPT3	15	coast input impulse option IOPT3 = 0 no incremental rates input IOPT3 = 1 input pitch yaw and roll incremental rates versus time during coast to compute impulse
IOPT4	20	CALCOMP plot option IOPT4 = 0 no plot IOPT4 = 1 CALCOMP plot output
IOPT5	25	boost and coast phase calculations IOPT5 = 0 boost phase only IOPT5 = +1 boost and coast phases IOPT5 = -1 coast phase only
IOPT6	30	boost phase impulse option IOPT6 = 0 boost phase impulse computed from disturbing moments and additional impulse IOPT6 = 1 boost phase impulse computed from incremental rates

The second and third card of input contains two lines of an arbitrary title which is output at the top of the printed page. Each card contains 80 columns of hollerith data. It is read with a format of (8A10).

3.4.2 Constants

Constants are input with fields of 10 columns. The fourth card contains five (5) time parameters as described below.

<u>FORTTRAN</u> <u>NAME</u>	<u>COLUMN</u>	<u>DESCRIPTION</u>
TP	sec	time of stage ignition (flight time)
TBO	sec	end of boost phase for stage being studied (flight time)
TSTEP	sec	output step size desired during the boost phase (this is also the integration step size for impulse expended)
TCOAST	sec	time of coast phase termination (flight time)
TSTEP C	sec	output step size for the coast phase

The next two cards of boost phase constants are input only if IOPT5 is zero or positive. The constants are read with format (6E10.3).

<u>FORTTRAN</u> <u>NAME</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
XT	x_r	inches	body station of booster nozzle throat
XC	x_c	inches	body station of pitch and yaw control motors
ZC	z_c	inches	location of pitch and yaw control motors away from centerline
RC	$12R_c$	inches	roll control motor moment arm
WH202I	W_c	lbs	weight of control fuel onboard at stage ignition
CNAS	$C_{N\alpha} S$	ft ² /deg	aerodynamic normal force coefficient slope at zero angle of attack times reference area
XCP	x_{cp}	inches	body station of aerodynamic center at zero angle of attack
ETA	λ_c	degrees	pitch and yaw control motor forward cant angle
CN3	$a_3 S$	ft ² /deg ³	cubic coefficient in aerodynamic normal force times reference area
DCP	$\partial x_{cp} / \partial \alpha$	inch/deg	incremental change in aerodynamic center per degree angle of attack

3.4.3 Boost Phase Tables (IOPT5 = 0, +1)

When the boost phase disturbances are analyzed (IOPT5 = 0 or +1) the following eight (8) tables are input: dynamic pressure, angle of attack, angle of sideslip, booster thrust, weight of booster propellant remaining versus time, and roll moment of inertia, pitch or yaw moment of inertia, and center of mass versus percent propellant consumed. The first three tables of aerodynamic parameters are input with format (I5/(7E10.3)). The first card of each table is an integer number of values to be read into the table. This number is input in columns 1 through 5 and must be right justified. The table is entered with alternating values of abscissa and ordinate with seven (7) numbers per card. These three tables are dimensioned for 300 numbers. See Figure 5 for the sample problem input. The descriptions follow.

<u>FORTTRAN</u> <u>NAME</u>	<u>NO. OF</u> <u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NQ	1	--	--	--	--	number of values in table Q
Q	NQ	t_f	sec	Q	lbs/ft ²	dynamic pressure versus flight time
NALPH	1	--	--	--	-	number of values in table ALPH
ALPH	NALPH	t_f	sec	α	deg	angle of attack versus flight time
NBETA	1	--	--	--	-	number of values in table BETA
BETA	NBETA	t_f	sec	β	deg	angle of sideslip versus flight time

The remaining input tables are dimensioned for 200 numbers each. These are read with format (I5/(6F10.3)). The first card of each table contains an integer number (right justified in columns 1 through 5) indicating the number of numbers included in the table. The table is read in with alternating abscissas and ordinates in fields of ten (10) with six (6) numbers per card. The descriptions of these tables follow .

<u>FORTTRAN</u> <u>NAME</u>	<u>NO. OF</u> <u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NTT	1	--	--	--	--	number of values in table TT
TT	NTT	t_s	sec	T	lbs	booster thrust versus time after stage ignition
NNWP	1	--	--	--	-	number of values in table WP
WP	NNWP	t_s	sec	W_{Prem}	lbs	booster propellant weight remaining versus time after booster ignition
NWX	1	--	--	--	-	number of values in table AIXX
AIXX	NWX	% W_{cons}	--	I_x	slug-ft ²	roll moment of inertia versus percent of booster propellant consumed
NWY	1	--	--	--	-	number of values in table AIYY

<u>FORTTRAN</u> <u>NAME</u>	<u>NO. OF</u> <u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
AIYY	NWY	%W _{cons}	--	I _y	slug-ft ²	pitch or yaw moment of inertia versus percent of booster propellant consumed
NXCG	1	--	--	--	-	number of values in table XCG
XCG	NXCG	%W _{cons}	--	x _{cg}	inches	center of mass body station versus percent of booster propellant consumed

3.4.4 Boost Phase Angular Accelerations (IOPT1 = 0)

Angular acceleration tables are input only when the boost phase is analyzed (IOPT5 = 0 or +1) and the acceleration input option IOPT1 = 0. These are read in with format (I5/(6E10.3)).

<u>FORTTRAN</u> <u>NAME</u>	<u>NO. OF</u> <u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NTHE	1	--	--	--	-	number of values in table THEDD
THEDD	NTHE	t _f	sec	$\ddot{\theta}$	deg/sec ²	pitch angular acceleration versus flight time when control motors are off
NPSI	1	--	--	--	-	number of values in table PSIDD
PSIDD	NPSI	t _f	sec	$\ddot{\psi}$	deg/sec ²	yaw angular acceleration versus flight time when control motors are off
NPHI	1	--	--	--	-	number of values in table PHIDD
PHIDD	NPHI	t _f	sec	$\ddot{\phi}$	deg/sec ²	roll angular acceleration versus flight time when control motors are off

3.4.5 Boost Phase Rate Slopes (IOPT1 = 1)

When IOPT1 = 1 and IOPT5 = 0 or +1 the angular accelerations are computed from the slopes of the rate traces and their scale factors (see paragraph 2.2.4 and equation 2-32). A single card containing the six (6) rate trace scale factors is input before the slope table. These are input with format (6E10.3) and have the following definitions:

FORTRAN			
<u>NAME</u>	<u>UNITS</u>	<u>COLUMNS</u>	<u>DESCRIPTION</u>
XKTHE	deg/sec/inch	1-10	pitch rate trace scale factor
XKPSI	deg/sec/inch	11-20	yaw rate trace scale factor
XKPHI	deg/sec/inch	21-30	roll rate trace scale factor
XKTP	inches/sec	31-40	pitch rate trace paper speed (inverse of time scale factor)
XKTY	inches/sec	41-50	yaw rate trace paper speed (inverse of time scale factor)
XKTR	inches/sec	51-60	roll rate trace paper speed (inverse of time scale factor)

Three tables of the pitch, yaw and roll rate trace slopes are entered next with format (I5/(6E10.3)).

FORTRAN NAME	NO. OF VALUES	ABSCISSA	UNITS	ORDINATE	UNITS	DESCRIPTION
NTHE	1	--	--	--	-	number of values in THEDD
THEDD	NTHE	t_f	sec	λ_θ	deg	pitch rate trace slope versus flight time when control motors are off
NPSI	1	--	--	--	-	number of values in table PSIDD
PSIDD	NPSI	t_f	sec	λ_ψ	deg	yaw rate trace slope versus flight time when control motors are off
NPHI	1	--	--	--	-	number of values in table PHIDD
PHIDD	NPHI	t_f	sec	λ_ϕ	deg	roll rate trace slope versus flight time when control motors are off

3.4.6 Incremental Impulse

Total impulse calculations include allowance for an incremental impulse which is precalculated. This allows for impulse not covered by moment balance during boost in any of three axes of control. It is up to the user to define entries into this table. This table is input with format (I5/6E10.3). The impulse is cumulative or a continuous sum.

<u>FORTTRAN</u>	<u>NO. OF</u>					
<u>NAME</u>	<u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NRI	1	--	--	--	-	number of values in table RI
RI	NRI	t_f	sec	I_T	lb-sec	sum of incremental impulse versus flight time

When (IOPT3 = 1) incremental rates are also used to compute impulse, such as, during limit cycle motion. Additional tables are required. These are input as an incremental absolute value of rate changes between time points (not cumulative). These incremental rates are summed in the program to estimate total impulse.

<u>FORTTRAN</u>	<u>NO. OF</u>					
<u>NAME</u>	<u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NDPR	1	--	--	--	-	number of values in table DPR
DPR	NDPR	t_f	sec	$\Delta \dot{\theta}$	deg/sec	incremental pitch rate between time points versus flight time (absolute values)
NDYR	1	--	--	--	-	number of values in table DYR
DYR	NDYR	t_f	sec	$\Delta \dot{\psi}$	deg/sec	incremental yaw rate between time points versus flight time (absolute values)
NDRR	1	--	--	--	-	number of values in table DRR
DRR	NDRR	t_f	sec	$\Delta \dot{\phi}$	deg/sec	incremental roll rate between time points versus flight time (absolute values)

3.4.7 Control Fuel

When IOPT2 = 0 the control fuel remaining versus flight time is input with format (I5/(6E10.3)).

<u>FORTTRAN</u>	<u>NO. OF</u>					
<u>NAME</u>	<u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NW	1	--	--	--	-	number of values in table W
W	NW	t_f	sec	W_c	lbs	control fuel weight remaining versus flight time

When IOPT2 = 1 the control fuel remaining is computed from the unregulated pressure and temperature of the pressurizing gas. The alternate input includes a card containing five (5) constants followed by two tables. These are,

<u>FORTTRAN</u>					
<u>NAME</u>	<u>COLUMN</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>	
DENS	1-10	ρ_L	lbs/in ³	density of liquid control fuel	
COMFAC	11-20	C_{reg}	--	compressibility factor of gas on regulated side	
PREREG	21-30	P_{reg}	psia	regulated pressure of system	
DVOL	31-40	ΔV_{reg}	in ³	initial volume of gas on regulated side of system	
VOLN2	41-50	V_g	in ³	volume of unregulated side of pressurization system	

The following tables are then entered with format (I5/6E10.3)).

<u>FORTTRAN</u>	<u>NO. OF</u>					
<u>NAME</u>	<u>VALUES</u>	<u>ABSCISSA</u>	<u>UNITS</u>	<u>ORDINATE</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
NNP	1	--	--	--	-	number of values in table P
P	NNP	t_f	sec	P_g	psia	unregulated gas pressure versus flight time
NNT	1	--	--	--	-	number of values in table T
T	NNT	t_f	sec	T_g	°F	unregulated gas temperature versus flight time

3.4.8 Coast Phase Constants (IOPT5 = -1)

When no boost phase is analyzed (IOPT5 = -1) nine (9) constants are input with format (6E10.3). These are,

<u>FORTTRAN</u>				
<u>NAME</u>	<u>COLUMN</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
RC	1-10	$12R_c$	inches	roll control motor moment arm
WH202I	11-20	W_{co}	lbs	value of control fuel onboard at stage ignition
YMA	21-30	$12 \cdot l_c$	inches	pitch or yaw control motor moment arm
R1XX	31-40	I_x	slug-ft ²	roll moment of inertia
Y1YY	41-50	I_y	slug-ft ²	pitch or yaw moment of inertia
WH202M	51-60	W_c	lbs	control fuel onboard at stage burnout

(next card)

WH202C	1-10		lbs	calculated control fuel at stage burnout
BOIMP	11-20	I_T	lb-sec	total impulse expended during boost phase
RIC	21-30	I_T	lb-sec	incremental impulse expended during the boost phase

3.4.9 CALCOMP Plot Variables (IOPT4 = 1)

This group of input data is required if the optional CALCOMP plots are desired (IOPT4 = 1). It includes scale factors, plot options and a title. The first card in this group is the title card containing 80 columns of alphanumeric information to be included at the top of each plot. It is read into array NTITLE with format (8A10). The next card contains the variable IROLL in column 5. This is an integer control constant;

IROLL = 0 no roll moment plotted
IROLL = 1 roll moment time history is plotted

The third card contains four scale factor constants. These are read with format (4E10.3) and are,

<u>FORTTRAN</u> <u>NAME</u>	<u>COLUMNS</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
SFT	1-10	sec/in	abscissa time scale factor of plots (note plot is limited to 7 inches along abscissa axis)
SFPYM	11-20	ft-lbs/in	pitch and yaw moment scale factor (plot is limited to ± 3 inches)
SFET	21-30	deg/in	thrust misalignment scale factor (plot is limited to ± 3 inches)
SFRM	31-40	ft-lbs/in	roll moment scale factor (plot is limited to ± 5 inches)

Note that there is no plotted information if the boost phase is deleted (IOPT5 = -1).

3.5 Output Data Description

Output includes printed data and optional CALCOMP plots (if IOPT4 = 1). A detailed description of the output is presented in the following paragraphs with a sample problem output of Figures 6 and 7 for reference. The printed output occurs in five basic pages,

- pitch boost phase variables
- yaw boost phase variables
- roll boost phase variables
- boost phase system summary data
- coast phase data

3.5.1 Boost Phase - Pitch (IOPT5 = 0, +1)

This page of output includes the time histories of pitch variables during the boost phase. Both stage time (measured from ignition) and flight time (measured from liftoff) are included. Refer to Figure 6 for the output layout. The definitions of the printed names follow,

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
FLIGHT TIME	t_f	sec	flight time
STAGE TIME	t_s	sec	stage time (measured from booster ignition)
ANGULAR ACCEL	$\ddot{\theta}$	deg/sec ²	pitch angular acceleration
MOMENT OF INER	I_y	slug-ft ²	pitch moment of inertia
AERO MOMENT	M_{aero}	ft-lbs	aerodynamic pitching moment (Equation 2-11)
MISALIGN MOMENT	M_r	ft-lbs	pitching moment due to booster (Equation 2-19)
TOTAL MOMENT	M_D	ft-lbs	total pitch disturbing moment (Equation 2-16)
THRUST MISALN	ϵ_{r_p}	deg	pitch component of effective thrust misalignment (Equation 2-21)
IMPULSE	I_T	lb-sec	total impulse due to pitch control motors during boost phase

3.5.2 Boost Phase - Yaw (IOPT5 = 0, +1)

This page format contains the following variables.

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
FLIGHT TIME	t_f	sec	flight time
STAGE TIME	t_s	sec	stage time measured from booster ignition
ANGULAR ACCEL	$\ddot{\psi}$	deg/sec ²	yaw angular acceleration
MOMENT OF INER	I_y	slug-ft ²	pitch or yaw moment of inertia
AERO MOMENT	N_{aero}	ft-lbs	yaw component of aerodynamic moment (Equation 2-12)
MISALIGN MOMENT	N_r	ft-lbs	yaw moment due to booster (Equation 2-20)

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
TOTAL MOMENT	N_D	ft-lbs	total yaw disturbing moment (Equation 2-17)
THRUST MISALN	ϵ_{ry}	deg	yaw component of effective thrust misalignment (Equation 2-22)
IMPULSE	I_T	lb-sec	yaw contribution to total impulse during boost phase

3.5.3 Boost Phase - Roll (IOPT5 = 0, +1)

This page format includes the following variables,

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
FLIGHT TIME	t_f	sec	flight time
STAGE TIME	t_s	sec	stage time measured from booster ignition
ANGULAR ACCEL	$\ddot{\phi}$	deg/sec ²	roll angular acceleration
MOMENT OF INER	I_x	slug-ft ²	roll moment of inertia
TOTAL MOMENT	L_D	ft-lbs	total roll disturbing moment (Equation 2-18)
IMPULSE	I_T	lb-sec	yaw contribution to total impulse during boost phase
C.G. POINT	x_{cg}	inches	body station of center of mass
CALCULATED CONSUM	W_c	lbs	calculated control fuel consumed based on total pitch yaw and roll impulse and average specific impulse (Equations 2-26)
CALCULATED REMAIN	$W_{c \text{ rem}}$	lbs	calculated control fuel remaining based on total impulse computed and average specific impulse

3.5.4 Boost Phase System Variables (IOPT5 = 0, +1)

This page format includes the following summary data,

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
FLIGHT TIME	t_f	sec	flight time
STAGE TIME	t_s	sec	stage time measured from booster ignition
THRUST	T	lbs	booster thrust
TOTAL MISALIGN	ϵ_r	deg	total effective booster thrust misalignment
LAMDA	λ_r	deg	roll orientation of thrust misalignment (Equation 2-24)
SPECIFIC IMPULSE	I_{sp}	sec	effective specific impulse during the boost phase (Equation 2-28)
TOTAL IMPULSE	I_T	lb-sec	total pitch yaw and roll impulse expended (Equation 2-26)
FUEL CONSUM	W_c	lbs	control fuel consumed measured or computed by Equation 2-29
FUEL REMAIN	W_{rem}	lbs	control fuel remaining based on measured or Equation 2-29

3.5.5 Coast Phase (IOPT5 = + 1)

This page of output includes the coast phase performance and total flight results on total impulse.

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
FLIGHT TIME	t_f	sec	flight time
STAGE TIME	t_s	sec	stage time measured from booster ignition
COAST IMPULSE	I_T	lb-sec	total impulse expended during coast

<u>LABEL</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>DESCRIPTION</u>
TOTAL IMPULSE	I_T	lb-sec	total impulse including boost and coast phases
COAST ISP	I_{sp}	lb _f -sec/lb _m	effective specific impulse during the coast phase
TOTAL ISP	I_{sp}	lb _f -sec/lb _m	effective specific impulse including boost and coast phases
COAST FUEL	W_c	lbs	control fuel consumed during the coast phase only
TOTAL FUEL	W_c	lbs	control fuel consumed including the boost and coast phases
FUEL REM MEAS	W_{rem}	lbs	control fuel remaining based on measured data or Equation (2-29)
FUEL REM CALC	W_{rem}	lbs	calculated control fuel remaining based on effective average specific impulse and impulse expended

3.5.6 CALCOMP Plots (IOPT4 = 1)

The optional CALCOMP plots include the pitch, yaw and roll disturbing moments and the effective thrust misalignment versus flight time. Plots from the sample problem are presented in Figure 7.

Figure 1
Sign Convention

(arrowheads denote positive sense)

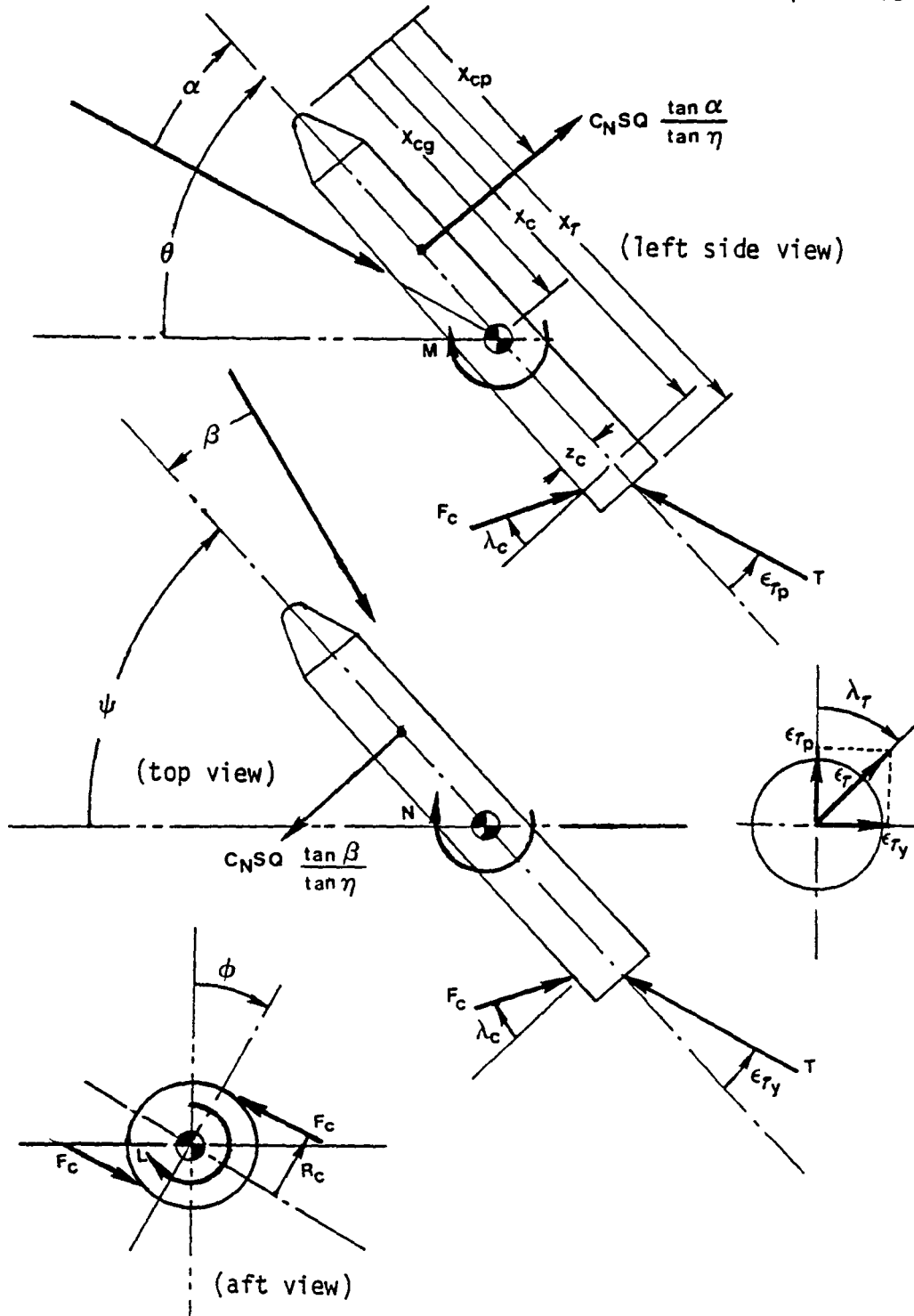


Figure 2
Disturbed and Undisturbed Motion

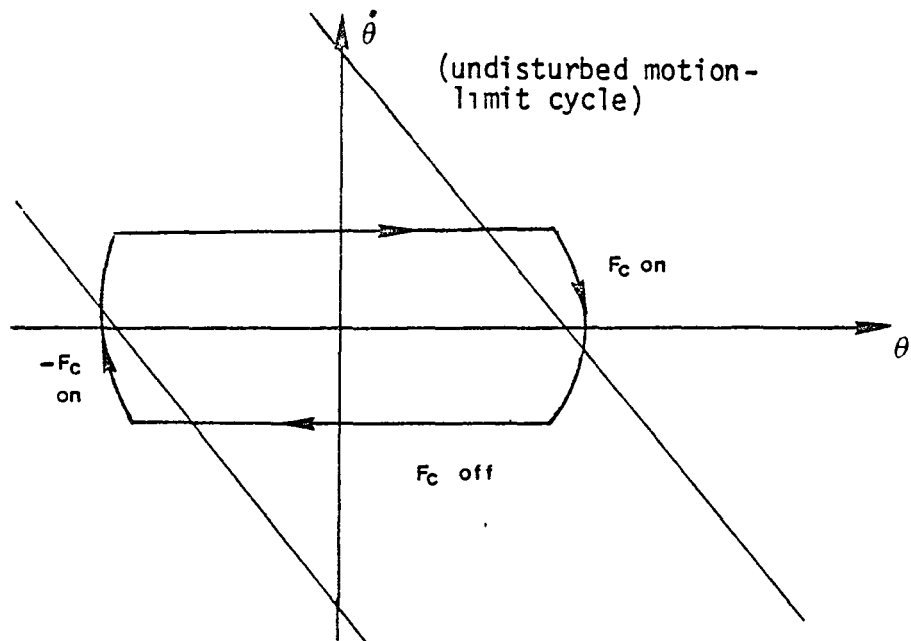
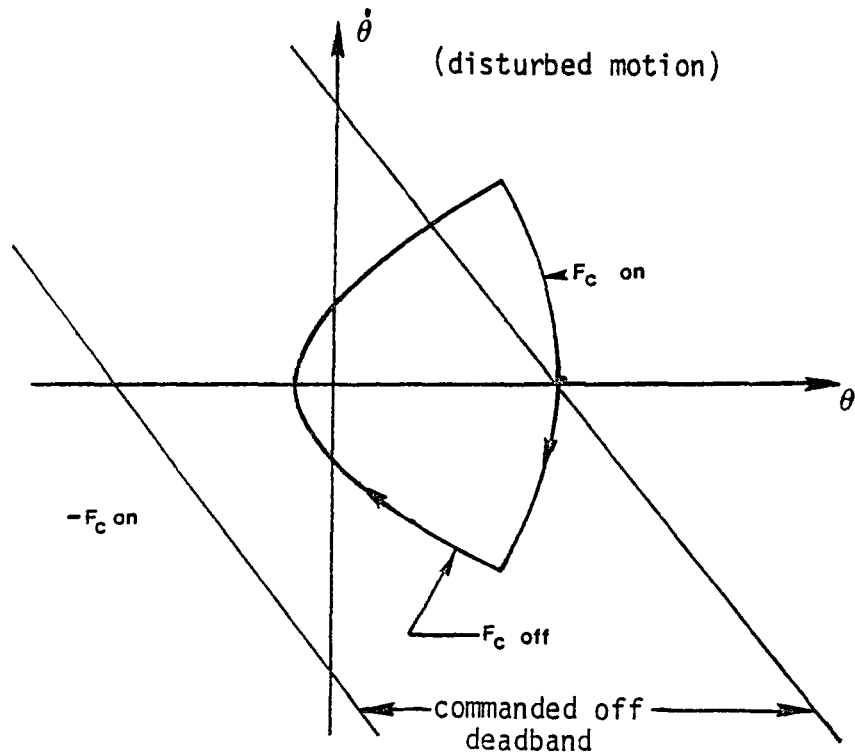


Figure 3
Typical Rate Time Histories

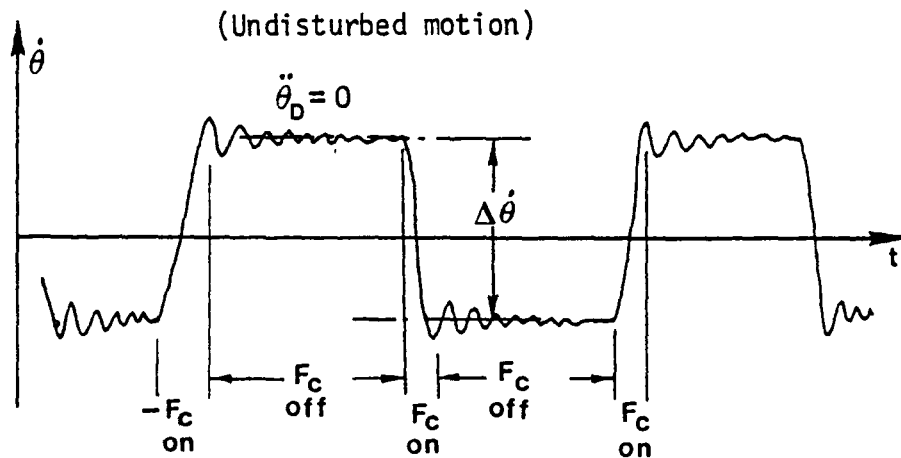
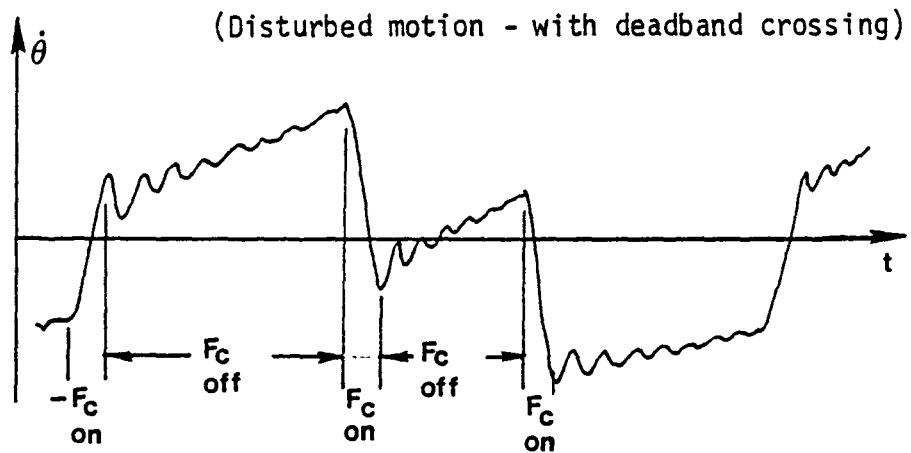
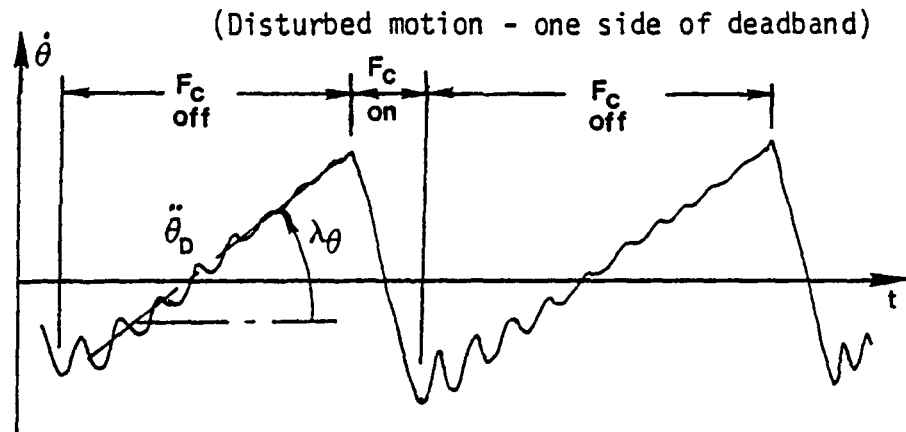


Figure 4
Flow Chart of UPSTAG

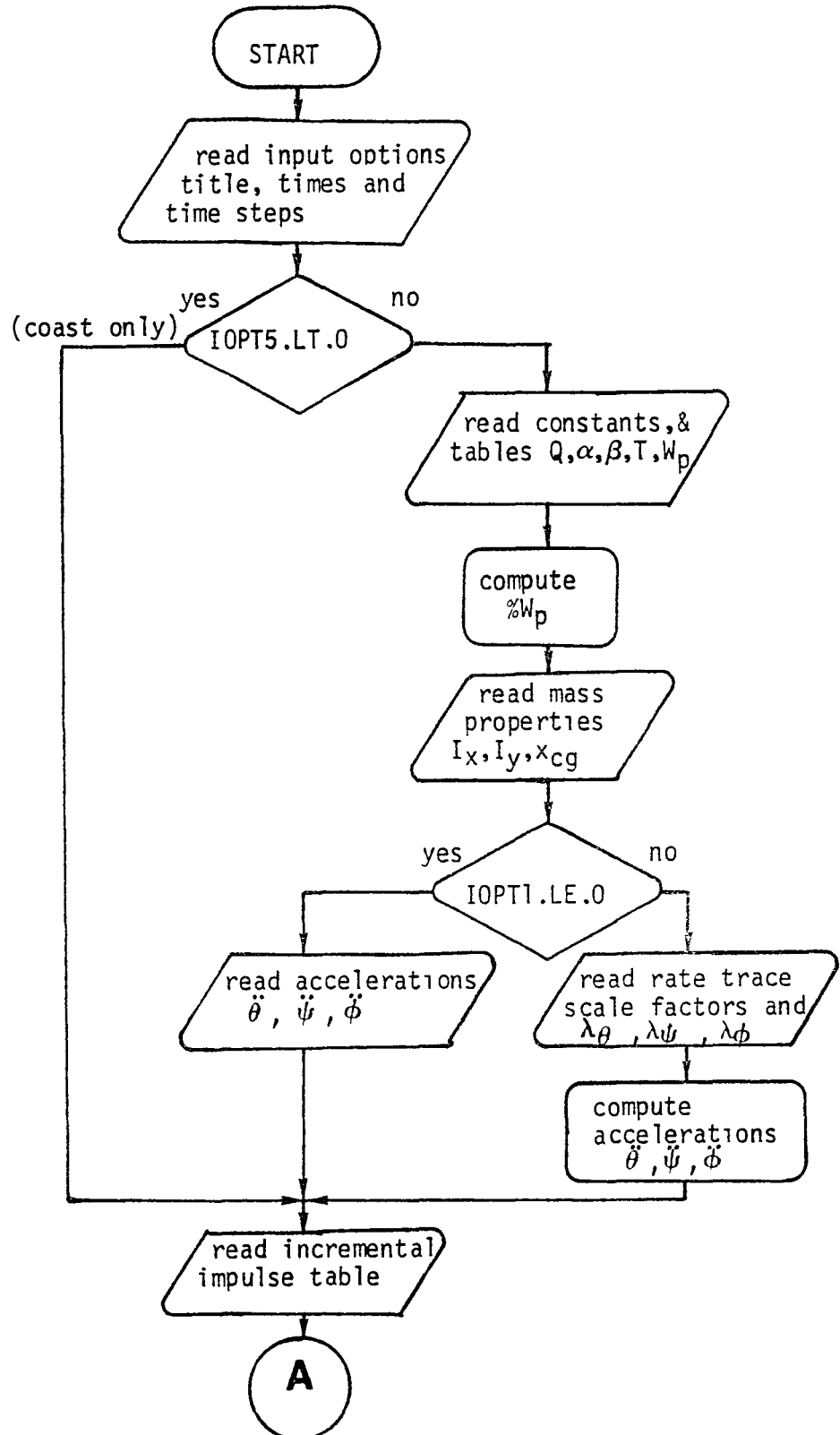


Figure 4 (continued)
Flow Chart of UPSTAG

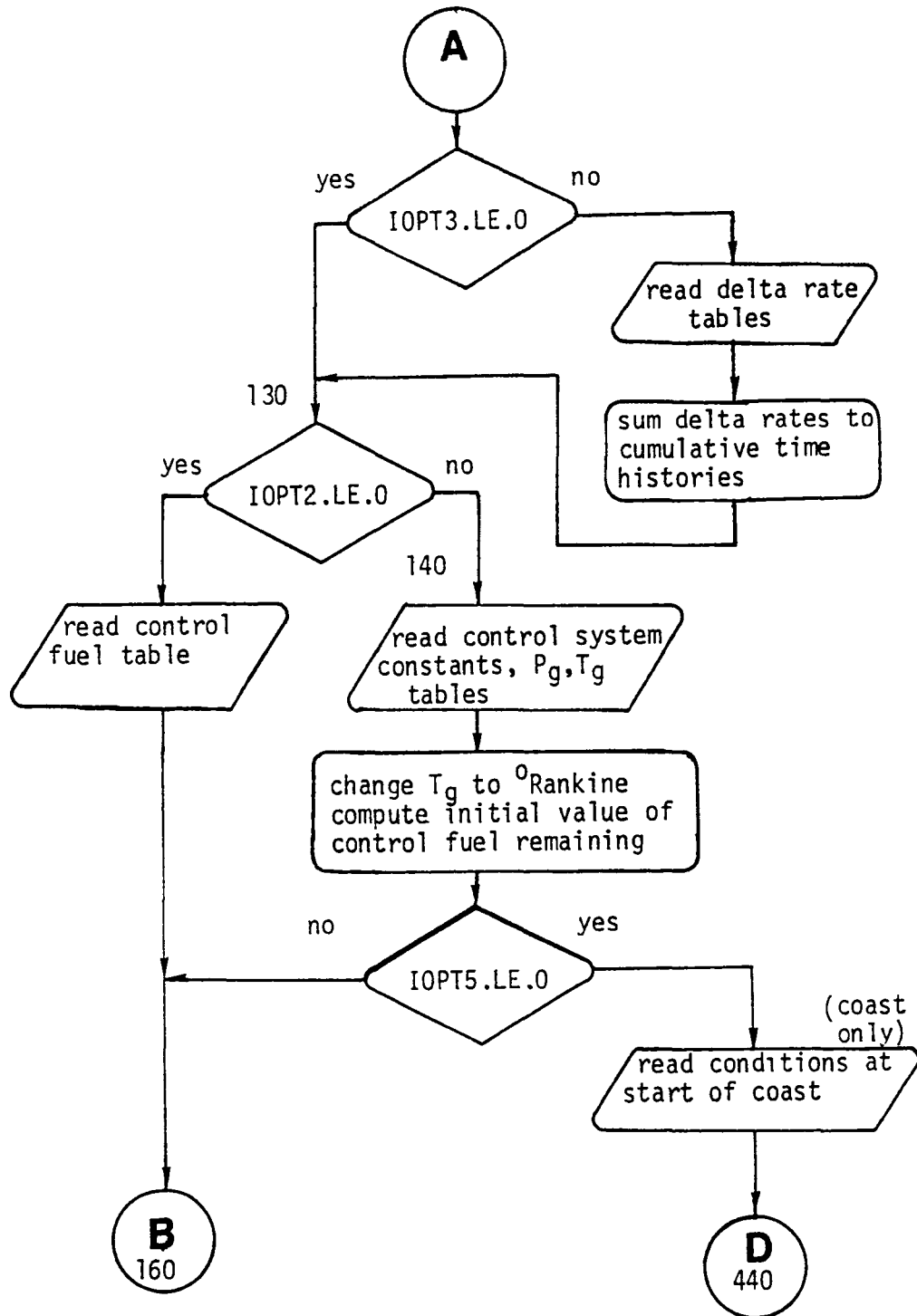


Figure 4 (continued)
Flow Chart of UPSTAG

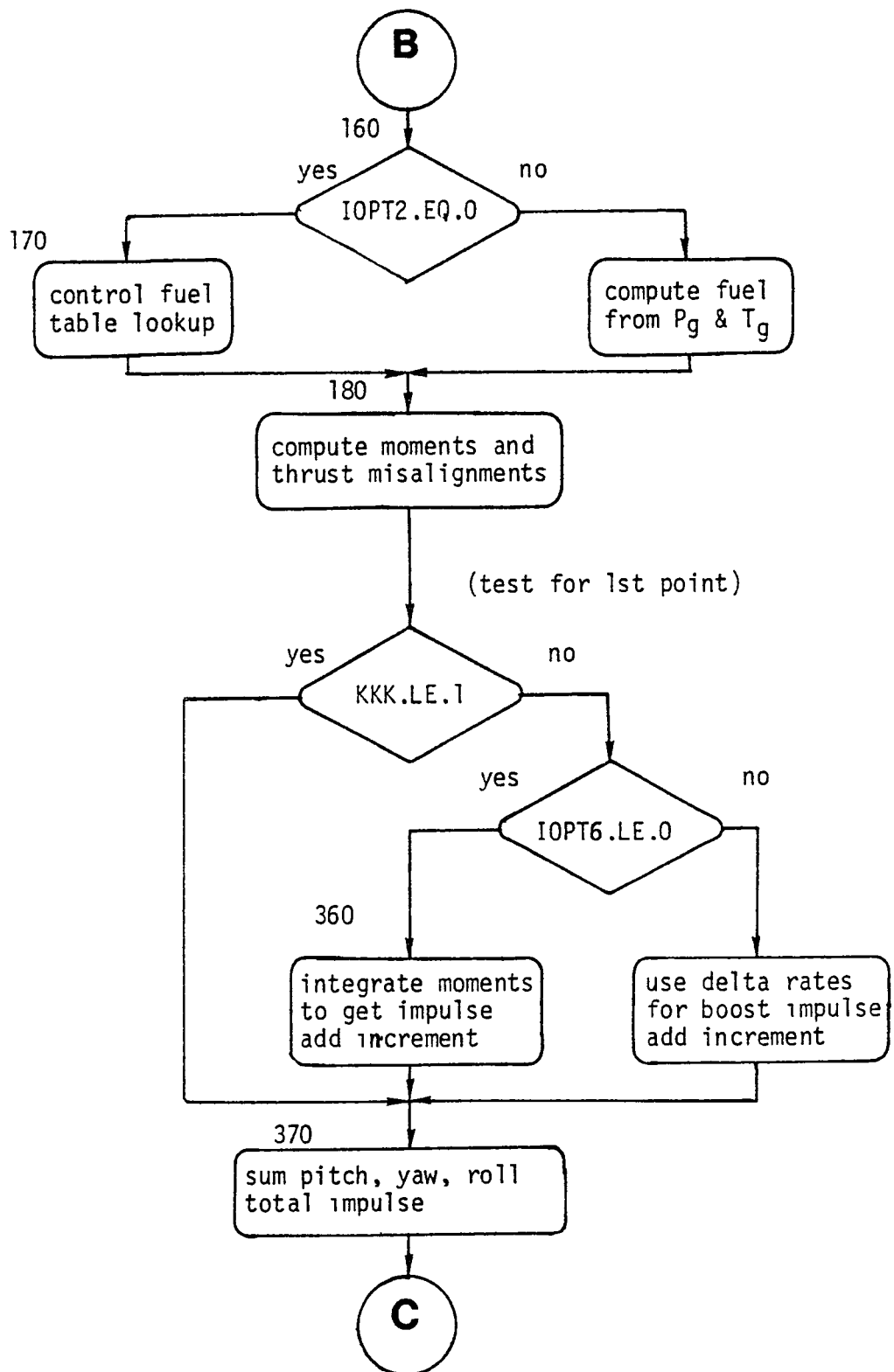


Figure 4 (continued)
Flow Chart of UPSTAG

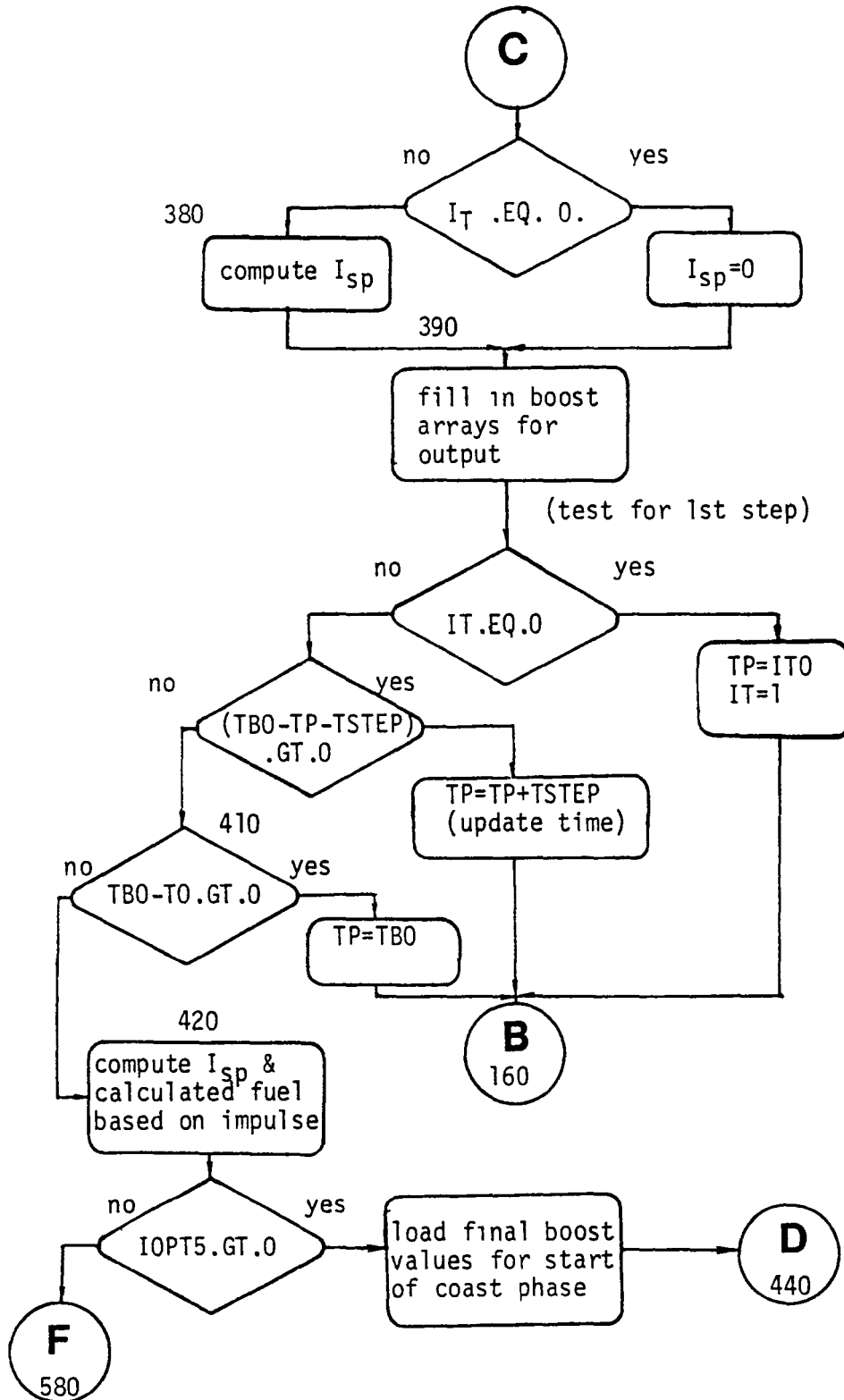


Figure 4 (continued)
Flow Chart of UPSTAG

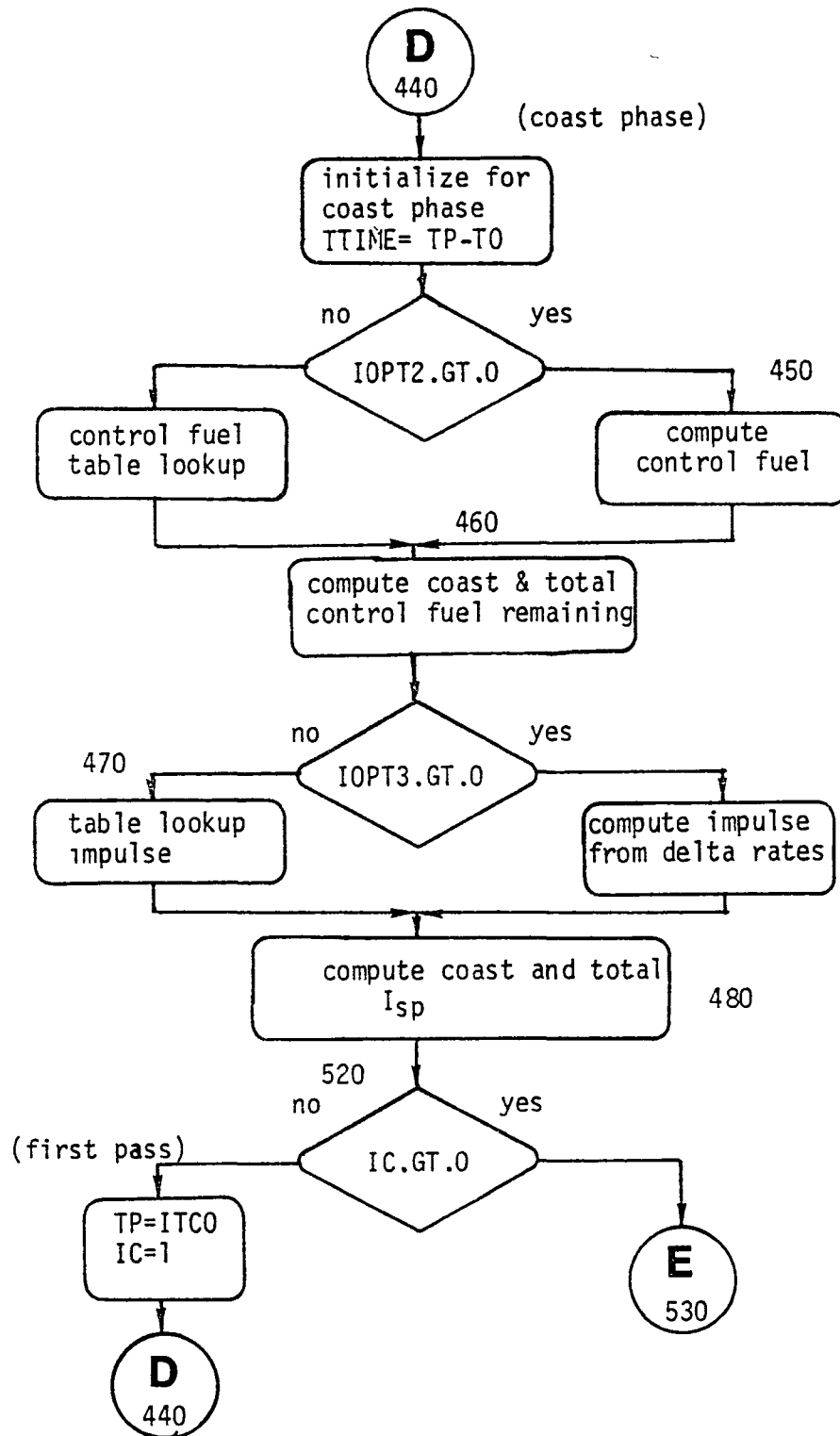


Figure 4 (continued)
Flow Chart of UPSTAG

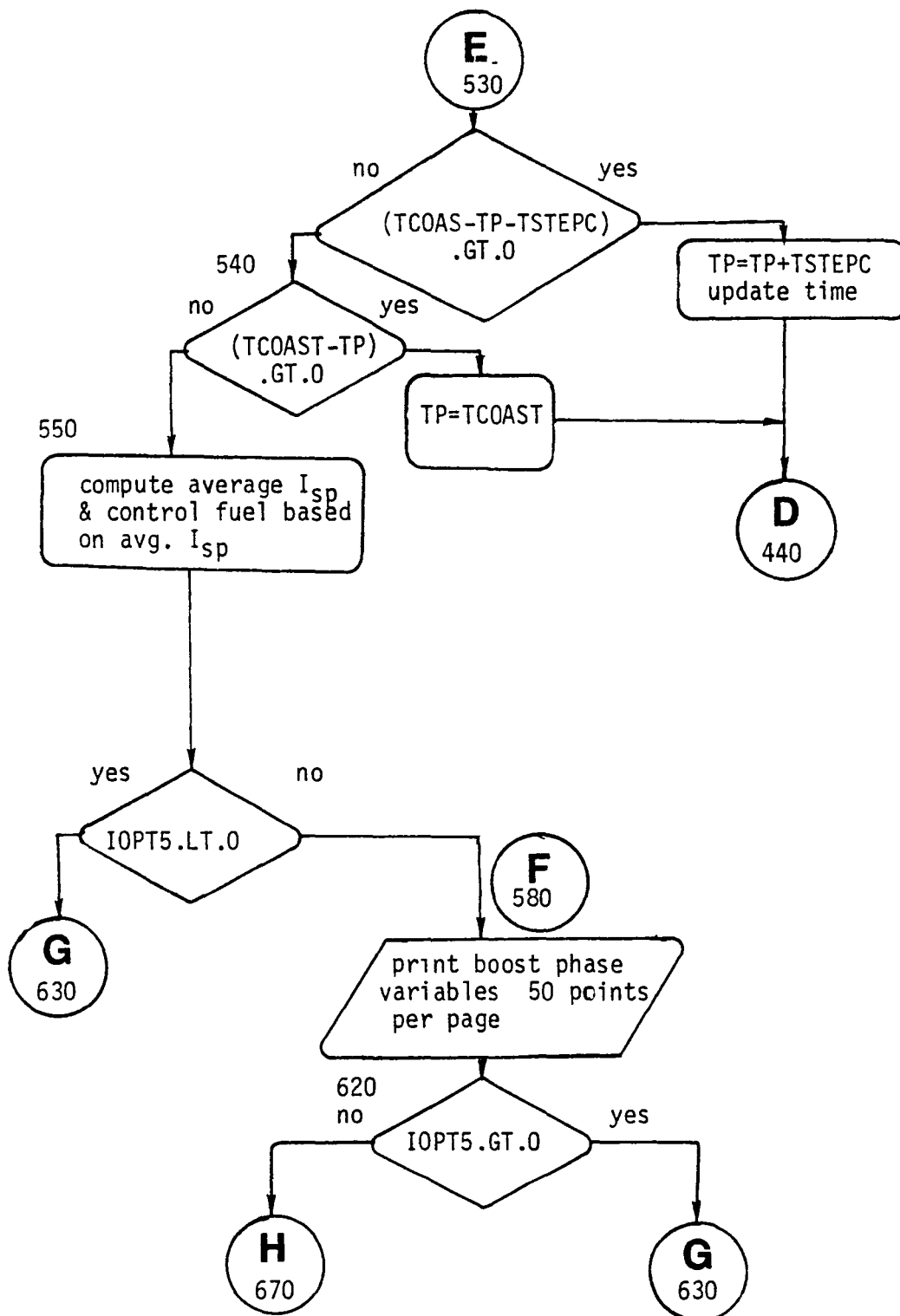


Figure 4 (concluded)
Flow Chart of UPSTAG

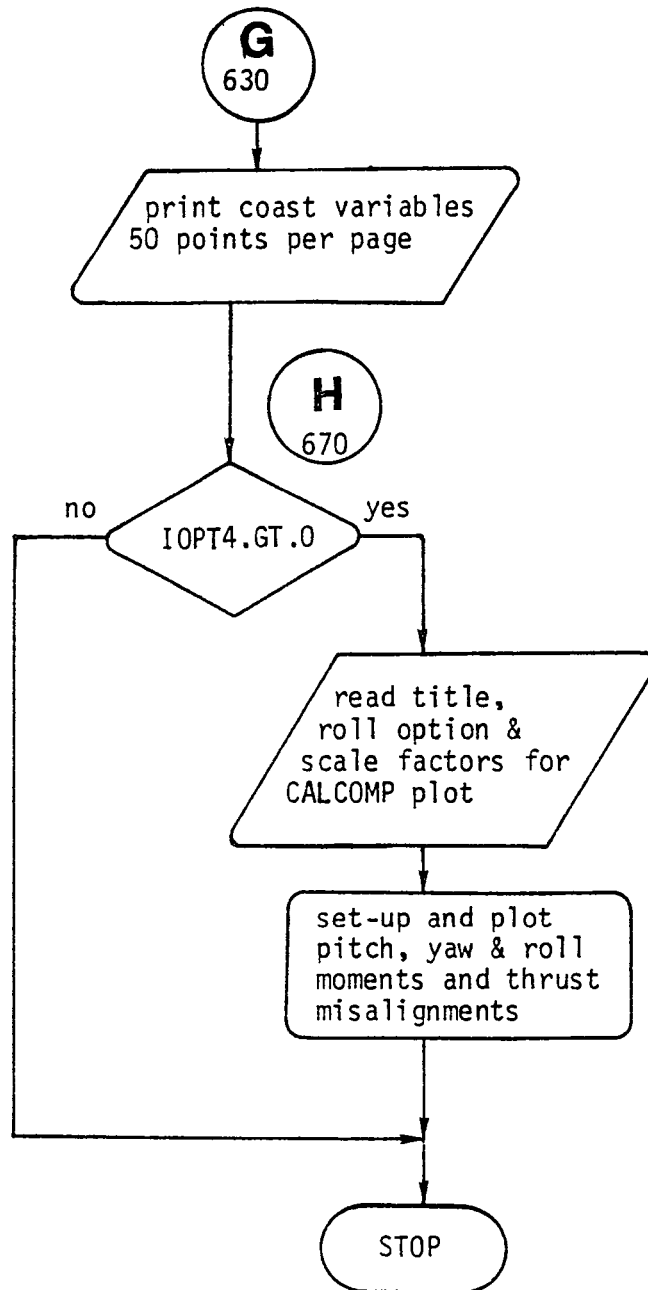


Figure 5
Sample Problem Input Data

1	0	1	1	1	0
SAMPLE PROBLEM FOR UPSTAG PROGRAM					
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS					
86.16	126.44	0.25	160.4	1.0	
448.51	467.76	14.93	16.89	119.3	0.472
109.0	5.0	0.00358	6.3		
222	Q DYNAMIC PRESSURE				
84.000	138.680	84.500	131.201	85.000	124.079
118.106	86.000	112.148	86.500	106.786	87.000
87.500	95.946	88.000	90.751	88.500	86.363
84.740	89.500	82.326	90.000	79.853	90.500
91.000	75.215	91.500	72.610	92.000	69.868
67.020	93.000	64.742	93.500	63.296	94.000
94.500	60.204	95.000	58.548	95.500	56.802
54.926	96.500	52.932	97.000	51.202	97.500
98.000	50.252	98.500	49.688	99.000	48.966
48.175	100.000	47.271	100.500	46.257	101.000
101.500	43.869	102.000	42.476	102.500	41.000
39.436	103.500	37.732	104.000	35.870	104.500
105.000	33.763	105.500	33.372	106.000	32.956
32.511	107.000	31.957	107.500	31.278	108.000
108.500	29.649	109.000	28.698	109.500	27.650
26.515	110.500	25.259	111.000	23.909	111.500
112.000	20.100	112.500	17.952	113.000	15.659
13.171	114.000	10.499	114.500	10.009	115.000
115.500	9.585	116.000	9.311	116.500	9.003
8.664	117.500	8.285	118.000	7.894	118.500
119.000	7.023	119.500	6.524	120.000	6.320
6.120	121.000	5.900	121.500	5.601	122.000
122.500	4.992	123.000	4.632	123.500	4.223
3.807	124.500	3.368	125.000	3.158	125.500
126.000	2.739	126.500	2.532	127.000	2.325
2.121	128.000	1.918	128.500	1.716	129.000
129.500	1.324	130.000	1.235	130.500	1.146
1.058	131.500	.971	132.000	.883	132.500
133.000	.710	133.500	.625	134.000	.540
.455	135.000	.414	135.500	.386	136.000
136.500	.329	137.000	.301	137.500	.273
.245	138.500	.218	139.000	.190	
222	ALPHA				
84.000	.087	84.500	.136	85.000	.134
.123	86.000	.100	86.500	.231	87.000
87.500	.258	88.000	.252	88.500	.245
.212	89.500	.291	90.000	.197	90.500
91.000	.181	91.500	.217	92.000	.149
.085	93.000	.163	93.500	.097	94.000
94.500	.154	95.000	.215	95.500	.292
.217	96.500	.312	97.000	.333	97.500
98.000	.462	98.500	.494	99.000	.449
.539	100.000	.588	100.500	.504	101.000
101.500	.535	102.000	.428	102.500	.397
.509	103.500	.373	104.000	.273	104.500
105.000	.213	105.500	.164	106.000	.210
.274	107.000	.215	107.500	.339	108.000
108.500	.231	109.000	.303	109.500	.205
.140	110.500	.183	111.000	.024	111.500
112.000	.050	112.500	-.003	113.000	.224
.050	114.000	.176	114.500	.159	115.000
115.500	.211	116.000	.097	116.500	.153
.246	117.500	.046	118.000	.210	118.500
119.000	.101	119.500	.272	120.000	.174
.371	121.000	.297	121.500	.182	122.000
122.500	.011	123.000	.092	123.500	.077
-.632	124.500	-.465	125.000	.032	125.500
126.000	-.295	126.500	-.065	127.000	-.691
-.167	128.000	-.280	128.500	-.445	129.000
129.500	-.235	130.000	-.480	130.500	-.753
-.518	131.500	-.077	132.000	-.215	132.500
133.000	-.636	133.500	-.854	134.000	-.397
-.074	135.000	-.246	135.500	-.418	136.000
136.500	-.774	137.000	-.929	137.500	-.291
-.136	138.500	-.316	139.000	-.437	

Figure 5 (continued)
Sample Problem Input Data

BETA						
222	84.000	-.440	84.500	-.417	85.000	-.359
	-.400	86.000	-.386	86.500	-.351	87.000
	87.500	.052	88.000	-.023	88.500	.021
	.248	89.500	.147	90.000	.081	90.500
	91.000	.276	91.500	.013	92.000	-.161
	-.279	93.000	-.273	93.500	-.216	94.000
	94.500	-.107	95.000	-.284	95.500	-.341
	-.315	96.500	-.262	97.000	-.140	97.500
	98.000	-.318	98.500	-.335	99.000	-.306
	-.138	100.000	.141	100.500	.075	101.000
	101.500	-.067	102.000	-.011	102.500	.127
	-.112	103.500	-.333	104.000	-.492	104.500
	105.000	-.580	105.500	-.400	106.000	-.140
	-.389	107.000	-.477	107.500	-.472	108.000
	108.500	-.180	109.000	-.013	109.500	.137
	.337	110.500	.288	111.000	-.107	111.500
	112.000	-.831	112.500	-.587	113.000	-.398
	-.224	114.000	.044	114.500	.163	115.000
	115.500	-.429	116.000	-1.006	116.500	-.818
	-.406	117.500	.022	118.000	-.013	118.500
	119.000	-.590	119.500	-.055	120.000	.505
	.304	121.000	-.083	121.500	.109	122.000
	122.500	.151	123.000	-.090	123.500	.094
	-.643	124.500	-.292	125.000	-.158	125.500
	126.000	.069	126.500	.092	127.000	-.322
	.292	128.000	.135	128.500	-.310	129.000
	129.500	.284	130.000	.459	130.500	.065
	-.348	131.500	.014	132.000	.450	132.500
	133.000	.062	133.500	-.339	134.000	-.013
	.400	135.000	.227	135.500	-.094	136.000
	136.500	-.081	137.000	.437	137.500	.100
	-.206	138.500	-.133	139.000	.404	
BOOSTER THRUST VERSUS TIME (CASTOR II)						
66	0.00	0.0	.21	42713.6	.46	40156.7
	1.86	44017.7	3.36	46204.6	6.36	51153.7
	8.36	54410.5	10.36	57460.7	12.36	60198.0
	14.36	62885.3	16.36	65194.0	18.36	67299.6
	20.36	68908.8	22.36	70342.4	23.86	71204.5
	25.86	71801.8	27.86	71612.4	29.36	71214.3
	30.86	70392.3	31.86	69206.1	34.96	69507.8
	35.56	67122.7	35.86	66835.9	35.96	65433.8
	36.46	27492.7	36.66	15760.3	36.86	10049.3
	37.26	5339.6	37.86	1697.8	38.36	440.0
	39.41	21.0	40.00	0.0	100.00	0.0
BOOSTER WEIGHT OF PROPELLANT REMAINING TIME HISTORY						
66	0.00	8274.34	.21	8253.70	.46	8213.68
	1.86	7984.04	3.36	7733.81	6.36	7197.29
	8.36	6805.81	10.36	6396.28	12.36	5967.30
	14.36	5511.28	16.36	5041.14	18.36	4557.46
	20.36	4056.87	22.36	3547.13	23.86	3159.52
	25.86	2643.79	27.86	2130.12	29.36	1746.67
	30.86	1372.14	31.86	1126.46	34.96	372.10
	35.56	227.09	35.86	157.85	35.96	133.41
	36.46	47.56	36.66	31.58	36.86	22.04
	37.26	10.67	37.86	2.87	38.36	.89
	39.41	0.00	40.00	0.00	100.00	0.00
IXX ROLL INERTIA VS. % PROPELLANT CONSUMED						
10	0.	427.80	25.	410.55	50.	367.84
	75.	299.68	100.	206.10		
IYY PITCH/YAW INERTIA VS. % PROPELLANT CONSUMED						
10	0.	49263.29	25.	45824.92	50.	41600.69
	75.	36058.32	100.	28031.35		
XCG VS. % PROPELLANT CONSUMED						
10	0.	282.03	25.	272.09	50.	258.44
	75.	238.53	100.	206.76		

Figure 5 (concluded)
Sample Problem Input Data

	2.825	2.841	2.318	3.96	3.96	3.96
108			PITCH	SLOPES		
	86.36	5.90	86.76	5.00	87.26	9.40
	87.86	7.60	88.86	6.20	89.86	6.90
	90.66	7.50	91.16	8.40	91.76	8.90
	92.76	8.90	93.56	9.50	94.46	9.50
	95.26	10.50	95.96	11.10	96.86	11.50
	97.56	11.50	98.36	11.50	99.06	12.50
	99.86	12.20	100.46	12.50	101.26	13.00
	101.96	12.70	102.76	13.00	103.36	12.80
	104.16	12.90	104.96	13.00	105.66	13.10
	106.46	13.00	107.16	13.70	107.86	14.20
	108.66	13.20	109.36	14.30	110.16	14.50
	110.96	12.60	111.86	12.50	112.66	13.40
	113.46	13.60	114.36	14.20	115.16	15.00
	116.46	15.10	117.06	15.80	117.56	15.90
	118.46	16.90	119.26	17.20	120.06	18.00
	120.96	19.00	121.46	20.00	121.76	21.30
	122.36	16.00	122.66	11.10	123.06	3.20
	123.66	.80	124.76	0.00	126.16	0.00
98			YAW	SLOPES		
	86.26	-2.50	87.16	-4.90	87.96	-2.80
	88.96	-4.90	89.46	-3.90	90.16	-1.90
	90.66	-2.50	91.46	-3.00	92.06	-1.20
	93.16	-1.00	94.06	-2.40	94.66	-2.60
	95.66	-1.90	96.36	-2.10	97.06	-3.00
	97.46	-2.10	98.66	-2.40	99.66	-2.10
	100.46	-3.80	101.16	-2.50	102.16	-2.20
	102.96	-2.30	103.96	-2.00	105.16	-1.80
	105.76	-2.20	106.56	-3.00	107.16	-2.40
	108.16	-1.00	109.16	-.30	110.16	-.80
	111.16	0.00	112.16	.80	113.16	1.00
	114.16	.30	115.66	.20	116.66	.20
	117.36	.10	119.36	.50	120.66	.60
	121.66	-.30	122.26	3.50	122.41	0.00
	122.66	-1.00	123.06	-2.70	123.26	.70
	123.86	1.00	124.46	-.20	125.16	0.00
186.16	0.00					
58			ROLL	SLOPES		
	86.96	3.50	87.96	1.20	88.76	.10
	89.96	1.10	91.66	1.00	93.56	1.00
	95.16	1.50	96.76	1.10	98.36	1.00
	99.06	1.50	99.76	1.20	101.16	1.00
	103.36	1.20	104.86	.90	105.46	0.00
	107.06	-.60	107.76	-1.00	108.56	-1.40
	109.16	-1.40	110.86	-.60	111.76	-2.00
	112.76	-.60	113.46	-.40	114.16	0.00
	118.16	0.00	121.66	0.00	122.36	2.00
123.16	0.00	186.16	0.00			
22			INCREMENTAL IMPULSE US.	FLIGHT TIME		
	86.	0.0	98.	0.0	102.	2.8
	106.	3.9	110.	7.3	114.	63.0
	118.	209.3	122.	419.0	124.	530.0
	126.	981.0	160.	981.0		
22			PITCH DELTA RATES DURING COAST			
	0.	0.00	126.	0.00	130.	8.94
	134.	5.44	138.	3.48	142.	3.56
	146.	0.00	150.	3.87	154.	0.00
	156.	5.09	160.	1.92		
22			YAW DELTA RATES DURING COAST			
	0.	0.00	126.	0.00	130.	10.62
	134.	5.11	138.	5.22	142.	7.27
	146.	6.99	150.	5.22	154.	7.44
	156.	5.34	160.	3.58		
4			ROLL DELTA RATES DURING COAST			
	0.	0.	160.	0.		
32			CONTROL FUEL REMAINING US.	FLIGHT TIME		
	80.	119.4	90.	119.35	95.	114.7
	100.	109.7	105.	104.2	110.	99.8
	115.	95.8	120.	90.3	125.	84.6
	130.	78.2	135.	75.8	140.	73.3
	145.	70.1	150.	68.5	155.	67.6
	160.	66.0				
SAMPLE PROBLEM - SCOUT S-1920 SECOND STAGE DISTURBANCES						
1 CALCOMP PLOT OPTION WITH ROLL PLOT						
1EOR	10.	2000.	0.1	2.		

Figure 6
Sample Problem Printed Output Data

UPPER STAGE MOMENT ROUTINE
PITCH VARIABLES TIME HISTORIES

PAGE - 1 A

SAMPLE PROBLEM FOR UPSTAG PROGRAM
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS

FLIGHT TIME SEC	STAGE TIME SEC	ANGULAR ACCEL DEG/S/S	MOMENT OF INER. SLUG-FT ²	AERO MOMENT FT-LB	MISALIGN MOMENT FT-LB	TOTAL MOMENT FT-LB	THRUST MISALN DEG	IMPULSE LB-SEC
86.16	0.00	1.16	49263.3	105.23	888.61	993.84	0.0000	0.00
87.00	.84	1.40	49058.9	113.94	1082.82	1196.76	.1082	59.07
88.00	1.84	1.45	48786.2	153.04	1084.68	1237.73	.1011	136.89
89.00	2.84	1.23	48509.0	119.37	925.81	1045.18	.0831	209.56
90.00	3.84	1.37	48222.1	104.41	1052.34	1156.74	.0908	279.34
91.00	4.84	1.59	47924.9	89.54	1244.08	1333.62	.1032	357.91
92.00	5.84	1.75	47627.6	68.37	1387.64	1456.01	.1108	445.52
93.00	6.84	1.79	47316.9	68.71	1407.59	1476.30	.1083	537.19
94.00	7.84	1.87	46991.5	98.60	1436.56	1535.16	.1066	630.88
95.00	8.84	2.01	46659.0	80.91	1554.03	1634.94	.1114	729.01
96.00	9.84	2.20	46318.6	76.08	1700.88	1776.96	.1179	834.10
97.00	10.84	2.28	45970.5	108.24	1717.62	1825.86	.1155	944.50
98.00	11.84	2.28	45565.7	145.28	1664.50	1809.79	.1085	1055.19
99.00	12.84	2.46	45114.5	136.39	1802.36	1938.76	.1140	1168.49
100.00	13.84	2.43	44648.9	170.46	1725.25	1895.71	.1058	1283.52
101.00	14.84	2.55	44176.3	145.90	1819.42	1965.33	.1085	1398.47
102.00	15.84	2.52	43696.3	109.93	1814.84	1924.76	.1054	1513.40
103.00	16.84	2.57	43209.6	119.75	1815.33	1935.07	.1028	1626.57
104.00	17.84	2.56	42715.8	57.72	1849.10	1906.82	.1021	1738.34
105.00	18.84	2.58	42213.6	41.85	1861.59	1903.44	.1005	1848.33
106.00	19.84	2.59	41702.5	40.36	1847.79	1888.15	.0978	1956.92
107.00	20.84	2.69	41057.8	39.05	1891.23	1930.28	.0978	2065.11
108.00	21.84	2.79	40374.9	57.26	1911.69	1968.95	.0966	2174.32
109.00	22.84	2.73	39687.5	48.14	1845.67	1893.81	.0912	2281.29
110.00	23.84	2.88	38995.1	20.14	1942.96	1963.10	.0941	2386.89
111.00	24.84	2.50	38304.2	3.09	1667.78	1670.87	.0794	2485.27
112.00	25.84	2.51	37613.3	5.16	1643.97	1649.13	.0770	2574.16
113.00	26.84	2.68	36925.1	17.93	1710.70	1728.63	.0793	2663.62
114.00	27.84	2.78	36237.0	9.38	1749.22	1758.60	.0802	2754.98
115.00	28.84	2.96	35325.0	4.40	1822.85	1827.26	.0825	2847.49
116.00	29.84	3.01	34344.1	4.17	1800.45	1804.62	.0805	2939.67
117.00	30.84	3.15	33375.2	9.73	1825.40	1835.14	.0808	3030.57
118.00	31.84	3.29	32421.6	7.42	1854.23	1861.65	.0821	3121.48
119.00	32.84	3.44	31477.1	3.01	1887.73	1890.75	.0821	3212.36
120.00	33.84	3.62	30532.8	4.52	1925.33	1929.85	.0823	3303.53
121.00	34.84	3.87	29588.6	7.03	1990.98	1998.01	.0836	3395.89
122.00	35.84	3.90	28661.8	8.88	1941.81	1950.70	.0835	3487.43
123.00	36.84	.86	28120.6	1.63	420.81	422.44	.1129	3541.99
124.00	37.84	.11	28043.5	-8.77	61.59	52.82	.0963	3552.91
125.00	38.84	0.00	28033.2	.38	-.38	0.00	-.0044	3554.12
126.00	39.84	0.00	28031.4	-3.05	3.05	0.00	1.5225	3554.12
126.44	40.28	0.00	28031.4	-.90	.90	0.00	0.0000	3554.12

Figure 6 (continued)
Sample Problem Printed Output Data

UPPER STAGE MOMENT ROUTINE
YAW VARIABLES TIME HISTORIES
PAGE - 1 B
SAMPLE PROBLEM FOR UPSTAG PROGRAM
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS

FLIGHT TIME SEC	STAGE TIME SEC	ANGULAR ACCEL DEG/S/S	MOMENT OF INER. SLUG-FT2	AERO MOMENT FT-LB	MISALIGN MOMENT FT-LB	TOTAL MOMENT FT-LB	THRUST MISALN DEG	IMPULSE LB-SEC
86.16	0.00	-.49	49263.3	277.92	-700.20	-422.28	0.0000	0.00
87.00	.84	-.88	49058.9	92.79	-846.47	-753.68	-.0845	31.71
88.00	1.84	-.57	48786.2	13.97	-496.52	-482.55	-.0463	71.23
89.00	2.84	-.95	48509.0	-139.64	-663.45	-803.09	-.0595	112.15
90.00	3.84	-.46	48222.1	-42.93	-346.87	-389.80	-.0299	149.95
91.00	4.84	-.53	47924.9	-136.54	-309.24	-445.78	-.0257	176.32
92.00	5.84	-.27	47627.6	73.88	-299.16	-225.28	-.0239	197.39
93.00	6.84	-.20	47316.9	115.07	-281.94	-166.87	-.0217	209.65
94.00	7.84	-.45	46991.5	33.27	-404.89	-371.63	-.0300	226.40
95.00	8.84	-.46	46659.0	106.88	-484.74	-377.86	-.0347	249.61
96.00	9.84	-.39	46318.6	110.44	-427.54	-317.10	-.0296	271.01
97.00	10.84	-.57	45970.5	45.51	-506.32	-460.82	-.0340	294.85
98.00	11.84	-.44	45565.7	100.00	-449.14	-349.14	-.0293	319.51
99.00	12.84	-.45	45114.5	92.95	-448.39	-355.43	-.0284	340.80
100.00	13.84	-.55	44648.9	-40.87	-391.39	-432.26	-.0240	364.43
101.00	14.84	-.55	44176.3	13.19	-436.98	-423.79	-.0261	389.92
102.00	15.84	-.44	43696.3	2.83	-339.59	-336.76	-.0197	412.39
103.00	16.84	-.45	43209.6	26.35	-365.29	-338.94	-.0207	432.20
104.00	17.84	-.39	42715.8	104.02	-395.90	-291.88	-.0219	450.55
105.00	18.84	-.36	42213.6	113.96	-378.27	-264.31	-.0204	466.61
106.00	19.84	-.48	41702.5	26.90	-375.80	-348.89	-.0199	484.17
107.00	20.84	-.50	41057.8	86.63	-447.04	-360.41	-.0231	504.27
108.00	21.84	-.24	40374.9	51.79	-221.17	-169.38	-.0112	519.11
109.00	22.84	-.08	39687.5	2.07	-58.10	-56.03	-.0029	525.35
110.00	23.84	-.14	38995.1	-48.47	-47.74	-96.21	-.0023	529.52
111.00	24.84	-.03	38304.2	13.78	-30.58	-16.80	-.0015	532.58
112.00	25.84	.13	37613.3	85.77	.84	86.62	.0000	534.45
113.00	26.84	.19	36925.1	31.86	90.63	122.49	.0042	539.98
114.00	27.84	.08	36237.0	-2.35	53.50	51.16	.0025	544.53
115.00	28.84	.05	35325.0	-10.59	40.13	29.53	.0018	546.62
116.00	29.84	.04	34344.1	43.21	-19.67	23.54	-.0009	547.96
117.00	30.84	.03	33375.2	16.07	1.25	17.32	.0001	548.98
118.00	31.84	.04	32421.6	.46	24.87	25.33	.0011	550.03
119.00	32.84	.08	31477.1	17.59	28.58	46.16	.0012	551.76
120.00	33.84	.11	30532.8	-13.12	70.58	57.46	.0030	554.24
121.00	34.84	.06	29588.6	1.97	27.84	29.81	.0012	556.29
122.00	35.84	.36	28661.8	-17.61	199.87	182.26	.0086	561.20
123.00	36.84	-.48	28120.6	1.60	-237.35	-235.76	-.0637	562.43
124.00	37.84	.14	28043.5	8.92	60.27	69.19	.0942	566.26
125.00	38.84	-.01	28033.2	1.90	-6.29	-4.39	-.0720	567.75
126.00	39.84	0.00	28031.4	-.71	.71	0.00	.3561	567.85
126.44	40.28	0.00	28031.4	-.87	.87	0.00	0.0000	567.85

Figure 6 (continued)
Sample Problem Printed Output Data

UPPER STAGE MOMENT ROUTINE
ROLL VARIABLES TIME HISTORIES
SAMPLE PROBLEM FOR UPSTAG PROGRAM
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS

PAGE - 1 C

FLIGHT TIME SEC	STAGE TIME SEC	ANGULAR ACCEL DEG/S/S	MOMENT OF INER SLUG-FT ²	TOTAL MOMENT FT-LB	IMPULSE LB-SEC	C.G. POINT INCH	CALCULATED FUEL CONSUM LB	REMAIN LB
86.16	0.00	.56	427.8	4.19	0.00	282.030	0.000	119.369
87.00	.84	.55	426.8	4.07	2.47	281.439	.669	118.700
88.00	1.84	.18	425.4	1.36	1.93	280.651	1.507	117.862
89.00	2.84	.05	424.0	.36	.61	279.849	2.313	117.057
90.00	3.84	.18	422.6	1.30	.59	279.020	3.084	116.285
91.00	4.84	.17	421.1	1.22	.90	278.161	3.839	115.530
92.00	5.84	.16	419.6	1.17	.85	277.301	4.619	114.750
93.00	6.84	.16	418.0	1.17	.83	276.403	5.364	114.005
94.00	7.84	.18	416.4	1.32	.89	275.462	6.157	113.212
95.00	8.84	.23	414.7	1.68	1.07	274.501	7.029	112.340
96.00	9.84	.21	413.0	1.49	1.13	273.517	7.937	111.432
97.00	10.84	.17	411.3	1.25	.97	272.511	8.899	110.470
98.00	11.84	.16	407.9	1.17	.86	271.252	9.869	109.500
99.00	12.84	.23	403.4	1.64	1.70	269.794	10.841	108.528
100.00	13.84	.19	398.7	1.30	2.45	268.290	11.841	107.528
101.00	14.84	.16	393.9	1.13	2.96	266.763	12.852	106.517
102.00	15.84	.17	389.0	1.17	3.62	265.212	13.843	105.526
103.00	16.84	.19	384.1	1.25	3.94	263.639	14.799	104.570
104.00	17.84	.17	379.1	1.14	4.20	262.043	15.735	103.634
105.00	18.84	.11	374.0	.72	4.29	260.421	16.640	102.729
106.00	19.84	-.03	368.9	-.21	4.08	258.769	17.543	101.826
107.00	20.84	-.09	361.2	-.58	5.03	256.490	18.471	100.899
108.00	21.84	-.18	352.8	-1.10	6.20	254.037	19.369	100.000
109.00	22.84	-.22	344.3	-1.35	7.32	251.567	20.189	99.180
110.00	23.84	-.16	335.8	-.94	8.11	249.080	20.983	98.387
111.00	24.84	-.13	327.3	-.75	21.83	246.598	21.809	97.560
112.00	25.84	-.27	318.8	-1.48	35.94	244.116	22.561	96.808
113.00	26.84	-.09	310.3	-.46	49.77	241.644	23.342	96.027
114.00	27.84	-.01	301.9	-.08	63.19	239.172	24.126	95.243
115.00	28.84	0.00	291.1	0.00	99.60	235.627	25.066	94.303
116.00	29.84	0.00	279.7	0.00	136.15	231.745	26.000	93.370
117.00	30.84	0.00	268.4	0.00	172.73	227.910	26.922	92.448
118.00	31.84	0.00	257.3	0.00	209.30	224.136	27.844	91.525
119.00	32.84	0.00	246.3	0.00	261.73	220.398	28.884	90.485
120.00	33.84	0.00	235.3	0.00	314.15	216.661	29.932	89.437
121.00	34.84	0.00	224.3	0.00	366.58	212.923	30.986	88.383
122.00	35.84	.16	213.4	.58	419.21	209.255	32.056	87.314
123.00	36.84	.06	207.1	.23	474.79	207.113	32.855	86.515
124.00	37.84	0.00	206.2	0.00	530.08	206.808	33.357	86.012
125.00	38.84	0.00	206.1	0.00	755.50	206.767	34.994	84.375
126.00	39.84	0.00	206.1	0.00	981.00	206.760	36.612	82.757
126.44	40.28	0.00	206.1	0.00	981.00	206.760	36.612	82.757

Figure 6 (continued)
Sample Problem Printed Output Data

UPPER STAGE MOMENT ROUTINE
TIME HISTORIES OF SYSTEM
SAMPLE PROBLEM FOR UPSTAG PROGRAM
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS

PAGE - 1 D

FLIGHT TIME SEC	STAGE TIME SEC	THRUST LB	TOTAL MISALGN DEG	LAMDA DEG	SPECIFIC IMPULSE SEC	TOTAL IMPULSE LB-SEC	FUEL CONSUM LB	FUEL REMAIN LB
86.16	0.00	0.	0.0000	0.00	0.00	0.00	0.00	119.37
87.00	.84	41205.	.1373	321.98	*****	93.24	.00	119.37
88.00	1.84	43963.	.1112	335.40	*****	210.05	.01	119.36
89.00	2.84	45446.	.1022	324.37	*****	322.32	.01	119.36
90.00	3.84	46996.	.0956	341.76	*****	429.88	.02	119.35
91.00	4.84	48646.	.1064	346.04	563.76	535.12	.95	118.42
92.00	5.84	50296.	.1133	347.83	342.58	643.77	1.88	117.49
93.00	6.84	51935.	.1104	348.67	266.15	747.68	2.81	116.56
94.00	7.84	53564.	.1107	344.26	229.51	858.17	3.74	115.63
95.00	8.84	55143.	.1167	342.67	209.82	979.68	4.67	114.70
96.00	9.84	56668.	.1216	345.89	195.13	1106.23	5.67	113.70
97.00	10.84	58118.	.1204	343.57	185.98	1240.32	6.67	112.70
98.00	11.84	59486.	.1124	344.90	179.36	1375.56	7.67	111.70
99.00	12.84	60843.	.1174	346.03	174.29	1510.99	8.67	110.70
100.00	13.84	62187.	.1085	347.22	170.69	1650.40	9.67	109.70
101.00	14.84	63439.	.1116	346.49	166.34	1791.35	10.77	108.60
102.00	15.84	64594.	.1072	349.40	162.56	1929.41	11.87	107.50
103.00	16.84	65699.	.1048	348.62	159.05	2062.70	12.97	106.40
104.00	17.84	66752.	.1045	347.91	155.88	2193.09	14.07	105.30
105.00	18.84	67686.	.1026	348.51	152.89	2319.22	15.17	104.20
106.00	19.84	68490.	.0998	348.50	152.35	2445.17	16.05	103.32
107.00	20.84	69253.	.1005	346.70	152.07	2574.41	16.93	102.44
108.00	21.84	69970.	.0972	353.40	151.59	2699.63	17.81	101.56
109.00	22.84	70618.	.0913	358.20	150.57	2813.96	18.69	100.68
110.00	23.84	71193.	.0941	358.59	149.44	2924.52	19.57	99.80
111.00	24.84	71497.	.0795	358.95	149.23	3039.67	20.37	99.00
112.00	25.84	71796.	.0770	.03	148.54	3144.55	21.17	98.20
113.00	26.84	71709.	.0794	3.03	148.09	3253.37	21.97	97.40
114.00	27.84	71614.	.0803	1.75	147.69	3362.70	22.77	96.60
115.00	28.84	71352.	.0825	1.26	148.23	3493.71	23.57	95.80
116.00	29.84	70951.	.0805	359.37	146.89	3623.78	24.67	94.70
117.00	30.84	70403.	.0808	.04	145.61	3752.28	25.77	93.60
118.00	31.84	69230.	.0821	.77	144.43	3880.81	26.87	92.50
119.00	32.84	69301.	.0821	.87	143.94	4025.85	27.97	91.40
120.00	33.84	69399.	.0823	2.10	143.52	4171.91	29.07	90.30
121.00	34.84	69496.	.0836	.80	142.96	4318.75	30.21	89.16
122.00	35.84	66855.	.0839	5.88	142.52	4467.84	31.35	88.02
123.00	36.84	10620.	.1296	330.57	140.95	4579.21	32.49	86.88
124.00	37.84	1819.	.1348	44.38	138.25	4649.25	33.63	85.74
125.00	38.84	248.	.0721	266.51	140.28	4877.37	34.77	84.60
126.00	39.84	6.	1.5636	13.17	141.56	5102.97	36.05	83.32
126.44	40.28	0.	0.0000	0.00	139.38	5102.97	36.61	82.76

(Note: ***** results when the computed number overflows the available output field width)

Figure 6 (concluded)
Sample Problem Printed Output Data

UPPER STAGE MOMENT ROUTINE
COAST VARIABLES TIME HISTORIES
SAMPLE PROBLEM FOR UPSTAG PROGRAM
SCOUT VEHICLE S-192C SECOND STAGE DISTURBING MOMENTS

PAGE - 1 E

FLIGHT TIME SEC	STAGE TIME SEC	COAST IMPULSE LB-SEC	TOTAL IMPULSE LB-SEC	COAST ISP SEC	TOTAL ISP SEC	COAST FUEL LB	TOTAL FUEL LB	FUEL REMAINING MEAS LB	FUEL REMAINING CALC LB
126.44	40.28	48.3	5151.3	0.00	140.96	0.00	36.54	82.76	82.35
127.00	40.84	109.9	5212.8	153.26	139.90	.72	37.26	82.04	81.84
129.00	42.84	329.6	5432.5	100.58	136.43	3.28	39.82	79.48	80.00
131.00	44.84	498.7	5601.6	99.01	134.72	5.04	41.58	77.72	78.58
133.00	46.84	617.2	5720.2	102.92	134.47	6.00	42.54	76.76	77.59
135.00	48.84	725.3	5828.3	104.26	133.98	6.96	43.50	75.80	76.68
137.00	50.84	823.0	5926.0	103.44	133.17	7.96	44.50	74.80	75.87
139.00	52.84	932.7	6035.7	104.13	132.65	8.96	45.50	73.80	74.95
141.00	54.84	1054.4	6157.3	104.43	132.02	10.10	46.64	72.66	73.93
143.00	56.84	1154.5	6257.4	101.47	130.58	11.38	47.92	71.38	73.09
145.00	58.84	1233.0	6335.9	97.42	128.78	12.66	49.20	70.10	72.43
147.00	60.84	1323.3	6426.2	99.52	128.94	13.30	49.84	69.46	71.68
149.00	62.84	1425.4	6528.4	102.27	129.33	13.94	50.48	68.82	70.82
151.00	64.84	1518.2	6621.2	105.16	129.88	14.44	50.98	68.32	70.05
153.00	66.84	1601.8	6704.8	108.25	130.60	14.80	51.34	67.96	69.35
155.00	68.84	1760.7	6863.7	116.17	132.76	15.16	51.70	67.60	68.02
157.00	70.84	1908.8	7011.8	120.83	133.97	15.80	52.34	66.96	66.78
159.00	72.84	1970.6	7073.5	119.89	133.51	16.44	52.98	66.32	66.26
160.40	74.24	2001.5	7104.4	119.44	133.29	16.76	53.30	66.00	66.00

*EOR

Figure 7
Sample Problem CALCOMP Plots

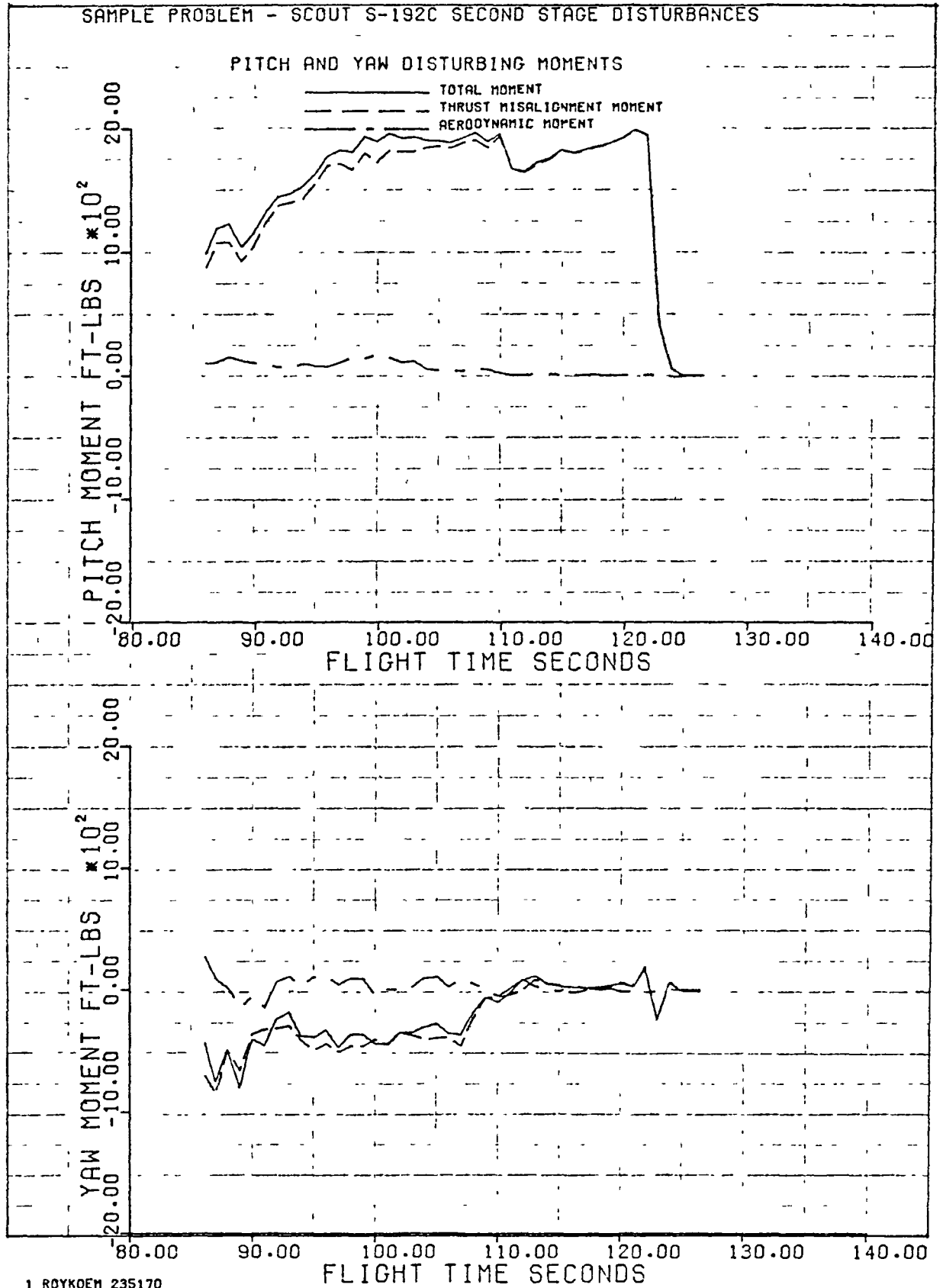


Figure 7 (continued)
Sample Problem CALCOMP Plots

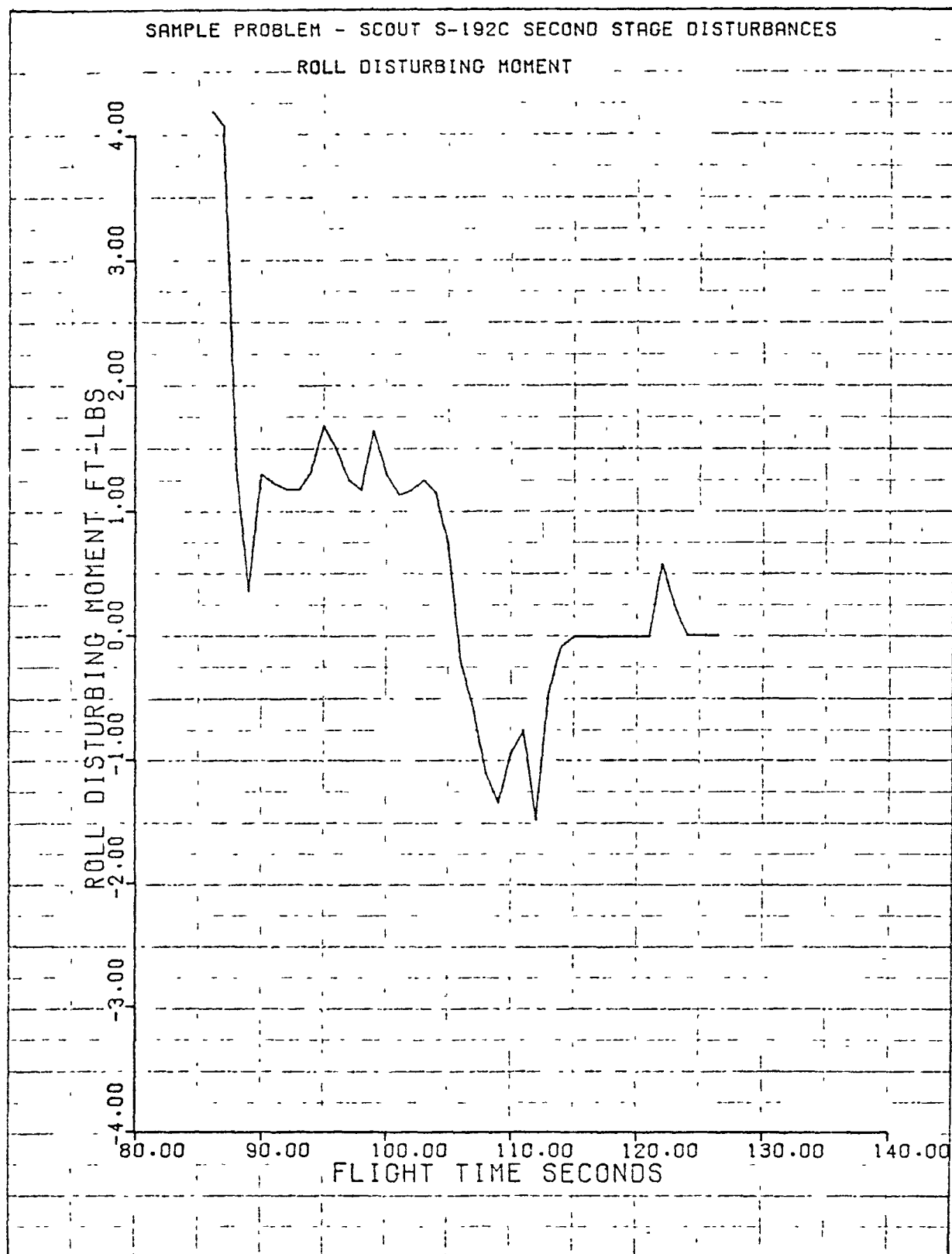
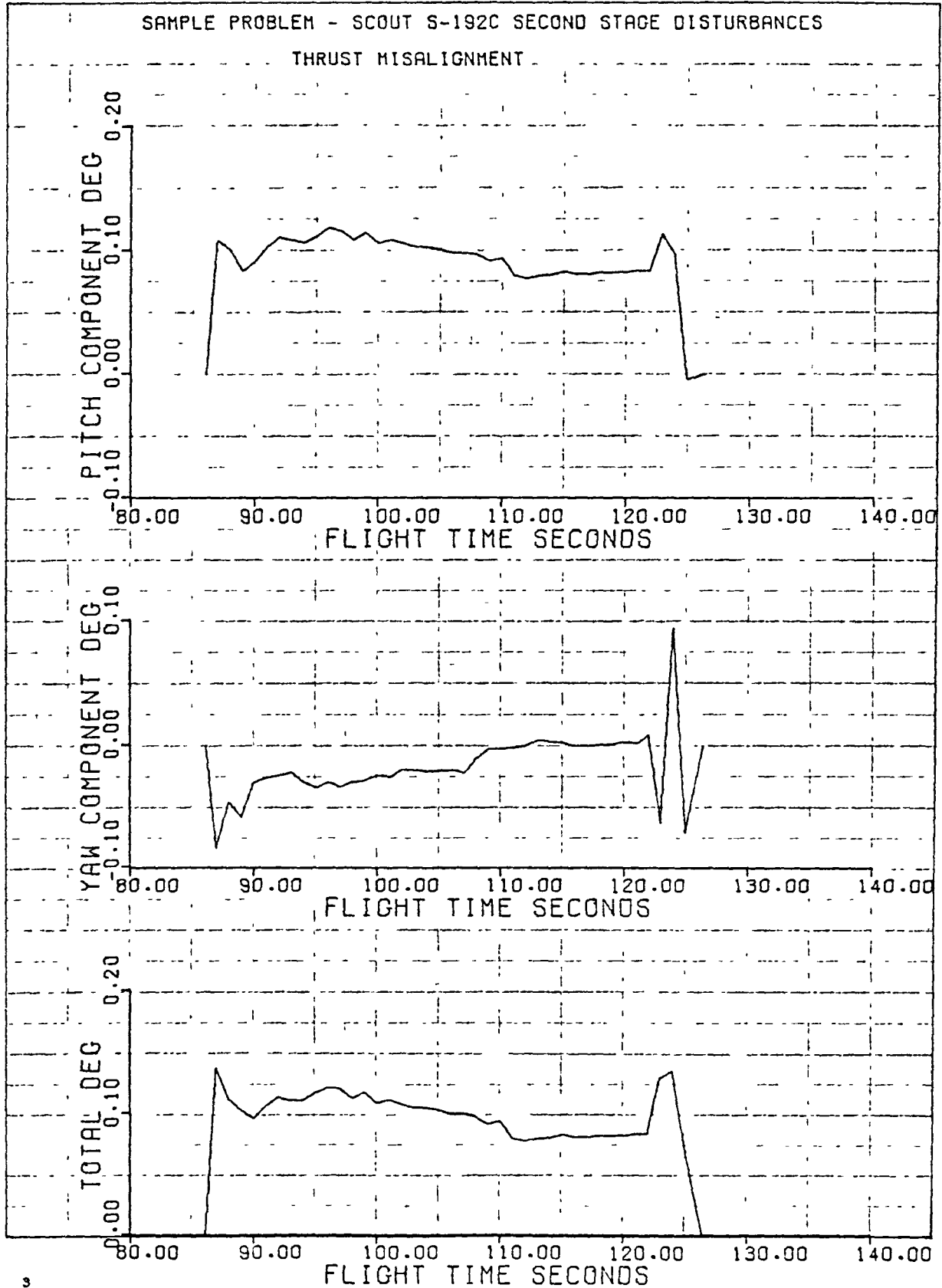


Figure 7 (concluded)
Sample Problem CALCOMP Plots



APPENDIX A

FORTRAN PROGRAM LISTING

A complete FORTRAN source program listing is presented in the following pages. It starts with the main routine (UPSTAG) and is followed by the subroutines arranged in alphabetical order. There are a total of 481 cards in UPSTAG. The total program including subroutines contains 805 cards.

*DECK	UPSTAG	1
	PROGRAM UPSTAG(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT)	2
C	UPSTAG IS A PROGRAM FOR POST-FLIGHT ANALYSIS OF THE PITCH, YAW	3
C	AND ROLL DISTURBANCES AND CONTROL FUEL CONSUMPTION FOR AN ON-OFF	4
C	REACTION CONTROLLED UPPER STAGE ROCKET VEHICLE.	5
	COMMON PVAR(200,9),YVAR(200,9),RVAR(200,9),TVAR(200,9)	6
	DIMENSION NTITLE(8),LTITL(16),P(200),T(200),U(200),DPR(200),	7
	1 DYR(200),DRR(200),THEDD(200),PHIDD(200),PSIDD(200),	8
	2 TT(200),UP(200),XCG(200),AIXX(200),AIYY(200),RI(200),	9
	3 Q(300),ALPH(300),BETA(300),CVAR(200,10),BRACK(200)	10
C	READ OPTIONS	11
	READ(5,830) IOPT1,IOPT2,IOPT3,IOPT4,IOPT5,IOPT6	12
C	READ TWO CARDS OF ARBITRARY LABELING	13
	READ(5,860) (LTITL(J),J=1,16)	14
C	READ TIME PARAMETERS	15
	READ(5,850) TO,TBO,TSTEP,TCOAST,TSTEP	16
C	INITIALIZE ALL COUNTERS, INDICES, AND SUMS	17
	AINI=0.0	18
	BINI=0.0	19
	CINI=0.0	20
	KKK=0	21
	LLL=0	22
	IC=0	23
	IT=0	24
	TP=TO	25
	ITO=TO+1.	26
	ITCO=TBO+1.	27
	MPHD=1	28
	MTT=1	29
	MQ=1	30
	MA=1	31
	MB=1	32
	MDP=1	33
	MDY=1	34
	MDR=1	35

	MR=1	36
	MP=1	37
	MT=1	38
	MU=1	39
	MUP=1	40
	MIX=1	41
	MIY=1	42
	MCG=1	43
	MTD=1	44
	MPSD=1	45
	IF (IOPT5 .LT. 0) GO TO 90	46
C	READ IN CONSTANTS	47
	READ(5,850) XT,XC,ZC,RC,WFUELI,CNAS,XCP,ETA,CN3,DCP	48
	ETA=ETA/57.3	49
C	READ AERODYNAMIC PARAMETER TABLES Q, ALPHA, BETA	50
	READ(5,880) NQ,(Q(I),I=1,NQ)	51
	READ(5,880) NALPH,(ALPH(I),I=1,NALPH)	52
	READ(5,880) NBETA,(BETA(I),I=1,NBETA)	53
C	READ IN BOOSTER THRUST AND PROPELLANT REMAINING TIME HISTORIES	54
	READ(5,840) NTT,(TT(I),I=1,NTT)	55
	READ(5,840) NNWP,(WP(I),I=1,NNWP)	56
C	CONVERT PROPELLANT REMAINING TO PER-CENT WEIGHT REMAINING	57
	WTIGN=WP(2)	58
	DO 10 I=2,NNWP,2	59
10	WP(I)=(WTIGN-WP(I))*100.0/WTIGN	60
C	READ IN MASS PROPERTIES VERSUS PERCENT BOOSTER PROPELLANT CONSUMED	61
	READ(5,840) NUX,(AIXX(I),I=1,NUX)	62
	READ(5,840) NWY,(AIYY(I),I=1,NWY)	63
	READ(5,840) NXCG,(XCG(I),I=1,NXCG)	64
C	TEST FOR INPUT OF ANGULAR ACCELERATION VALUES	65
	IF (IOPT1 .GT. 0) GO TO 20	66
C	READ IN ANGULAR ACCELERATIONS	67
	READ(5,840) NTHE,(THEDD(J),J=1,NTHE)	68
	READ(5,840) NPSI,(PSIDD(J),J=1,NPSI)	69
	READ(5,840) NPHI,(PHIDD(J),J=1,NPHI)	70

	GO TO 90	71
C		72
C	READ RATE TRACE SLOPE FACTORS	73
20	READ(5,850) XKTHE,XKPSI,XKPHI,XKTP,XKTY,XKTR	74
C	READ IN SLOPE ANGLES	75
	READ(5,840) NTHE,(THEDD(I),I=1,NTHE)	76
	READ(5,840) NPSI,(PSIDD(I),I=1,NPSI)	77
	READ(5,840) NPHI,(PHIDD(I),I=1,NPHI)	78
	DO 30 I=2,NTHE,2	79
30	THEDD(I)=THEDD(I)/57.3	80
	DO 40 I=2,NPSI,2	81
40	PSIDD(I)=PSIDD(I)/57.3	82
	DO 50 I=2,NPHI,2	83
50	PHIDD(I)=PHIDD(I)/57.3	84
C	CALCULATE ANGULAR ACCELERATIONS	85
	DO 60 I=2,NTHE,2	86
60	THEDD(I)=XKTHE*XKTP*TAN(THEDD(I))	87
	DO 70 I=2,NPSI,2	88
70	PSIDD(I)=XKPSI*XKTY*TAN(PSIDD(I))	89
	DO 80 I=2,NPHI,2	90
80	PHIDD(I)=XKPHI*XKTR*TAN(PHIDD(I))	91
C	TEST FOR INPUT OF ROLL IMPULSE TABLE	92
90	READ(5,840) NRI,(RI(I),I=1,NRI)	93
C	TEST FOR INPUT OF DELTA RATES	94
	IF (IOPT3 .LE. 0) GO TO 130	95
	READ(5,840) NDPR,(DPR(I),I=1,NDPR)	96
	READ(5,840) NDYR,(DYR(I),I=1,NDYR)	97
	READ(5,840) NDRR,(DRR(I),I=1,NDRR)	98
	DPRATE=0.0	99
	DYRATE=0.0	100
	DRRATE=0.0	101
	DO 100 I=2,NDPR,2	102
	DPR(I)=DPRATE+DPR(I)	103
100	DPRATE=DPR(I)	104
	DO 110 I=2,NDYR,2	105

	DYR(I)=DYRATE+DYR(I)	106
110	DYRATE=DYR(I)	107
	DO 120 I=2,NDRR,2	108
	DRR(I)=DRRATE+DRR(I)	109
120	DRRATE=DRR(I)	110
C	TEST FOR FUEL WEIGHT INPUT/CALCULATION	111
130	IF (IOPT2 .GT. 0) GO TO 140	112
C	READ IN FUEL WEIGHT DATA	113
	READ(5,840) NW,(W(I),I=1,NW)	114
	GO TO 160	115
C		116
C	FUEL WEIGHT CALCULATION	117
140	READ(5,850) DENS,COMFAC,PREREG,DUOL,VOLN2	118
	READ(5,840) NNP,(P(I),I=1,NNP)	119
	READ(5,840) NNT,(T(I),I=1,NNT)	120
	DO 150 I=2,NNT,2	121
150	T(I)=T(I)+460.0	122
	CONST1=DENS*COMFAC*VUOLN2/PREREG	123
	CONST2=DENS*DUOL	124
	CALL C (P(2),T(2),CI)	125
	IF (IOPT5 .GE. 0) GO TO 160	126
	READ(5,850) RC,WFUELI,YMA,RIXX,YIYY,WFUELM,WFUELC,BOIMP,RIC	127
	GO TO 440	128
C		129
160	CONTINUE	130
	TTIME=TP-T0	131
	KKK=KKK+1	132
C	GET FUEL FUEL REMAINING ARRAY	133
	IF (IOPT2 .EQ. 0) GO TO 170	134
	CALL TBLU (NNP,PRES,TP,P,MP)	135
	CALL TBLU (NNT,TEMP,TP,T,MT)	136
	CALL C (PRES,TEMP,CF)	137
	DW=CONST1*((P(2)*TEMP)/(CI*T(2))-PRES/CF)+CONST2*((TEMP/T(2))-1.0)	138
	TUAR(KKK,9)=WFUELI-DW	139
	GO TO 180	140

		141
		142
C	170 CALL TBLU (NW,UWT,TP,U,MU)	143
	TUAR(KKK,9)=UWT	144
	OBTAIN IXX,IYY,CP IN TERMS OF TIME	145
C	180 CALL TBLU (NNUP,UWP,TTIME,UP,MUP)	146
	CALL TBLU (NWX,AAIXX,UWP,AIXX,MIX)	147
	CALL TBLU (NWX,AAIYY,UWP,AIYY,MIY)	148
	CALL TBLU (NXCG,XXCG,UWP,XCG,MCG)	149
	COMPUTE THE SUM OF THE MOMENT DISTURBANCES	150
C	OBTAIN THE ANGULAR ACCELERATIONS FROM TABLE LOOKUP ROUTINE	151
C	CALL TBLU (NTHE,TTHEDD,TP,THEDD,MTD)	152
	CALL TBLU (NPSI,PPSIDD,TP,PSIDD,MPSD)	153
	CALL TBLU (NPHI,PPHIDD,TP,PHIDD,MPHD)	154
	COMPUTE THE SUM OF MOMENTS	155
C	PVAR(KKK,7)=AAIYY*TTHEDD/57.3	156
	YVAR(KKK,7)=AAIYY*PPSIDD/57.3	157
	RVAR(KKK,5)=AAIXX*PPHIDD/57.3	158
	DEFINE X1 AND X2	159
	X2=(XT-XXCG)/12.	160
C	COMPUTE THRUST MISALIGNMENT COMPONENTS	161
	CALL TBLU (NTT,TTT,TTIME,TT,MTT)	162
	CALL TBLU (NQ,QQ,TP,Q,MQ)	163
	CALL TBLU (NALPH,AALPH,TP,ALPH,MA)	164
	CALL TBLU (NBETA,BBETA,TP,BETA,MB)	165
	IF (AALPH.NE.0.) GO TO 190	166
	IF (BBETA.NE.0.) GO TO 190	167
	AERO=0.	168
	AB=0.	169
	PVAR(KKK,5)=0.	170
	YVAR(KKK,5)=0.	171
	GO TO 200	172
C	COMPUTE TOTAL AERODYNAMIC ANGLE AND AERODYNAMIC MOMENTS	173
C	190 TNA=TAN(AALPH/57.3)	174
	TNB=TAN(BBETA/57.3)	175

	TANETA=SQRT(TNA*TNA+TNB*TNB)	176
	AB=57.3*ATAN(TANETA)	177
	AERO=(CNAS*AB+CN3*AB**3)*QQ*(XXCG-XCP-DCP*ABS(AB))/12.	178
	PVAR(KKK,5)=AERO*TNA/TANETA	179
	YVAR(KKK,5)=-AERO*TNB/TANETA	180
200	PVAR(KKK,6)=PVAR(KKK,7)-PVAR(KKK,5)	181
	YVAR(KKK,6)=YVAR(KKK,7)-YVAR(KKK,5)	182
	IF (TTT .GT. 0.) GO TO 210	183
	ETP=0.0	184
	ETY=0.0	185
	GO TO 220	186
C		187
210	ETP=(PVAR(KKK,7)-PVAR(KKK,5))/(TTT*X2)	188
	ETY=(YVAR(KKK,7)-YVAR(KKK,5))/(TTT*X2)	189
C	COMPUTE TOTAL THRUST MISALIGNMENT	190
220	ETOT=SQRT(ETP**2+ETY**2)	191
	PVAR(KKK,8)=ETP*57.3	192
	YVAR(KKK,8)=ETY*57.3	193
	TVAR(KKK,4)=ETOT*57.3	194
	IF (ETP) 230,270,310	195
230	IF (ETY) 240,250,260	196
240	ETOR=ATAN(ETY/ETP)*57.3+180.0	197
	GO TO 350	198
C		199
250	ETOR=180.0	200
	GO TO 350	201
C		202
260	ETOR=ATAN(ETY/ETP)*57.3+180.0	203
	GO TO 350	204
C		205
270	IF (ETY) 280,290,300	206
280	ETOR=270.0	207
	GO TO 350	208
C		209
290	ETOR=0.0	210

	GO TO 350	211
C		212
	300 ETOR=90.0	213
	GO TO 350	214
C		215
	310 IF (ETY) 320,330,340	216
	320 ETOR=ATAN(ETY/ETP)*57.3+360.0	217
	GO TO 350	218
C		219
	330 ETOR=0.0	220
	GO TO 350	221
C		222
	340 ETOR=ATAN(ETY/ETP)*57.3	223
	350 TVAR(KKK,5)=ETOR	224
C	GET TIME ARRAY	225
	PVAR(KKK,1)=TP	226
	YVAR(KKK,1)=TP	227
	RVAR(KKK,1)=TP	228
	TVAR(KKK,1)=TP	229
	PVAR(KKK,2)=TTIME	230
	YVAR(KKK,2)=TTIME	231
	RVAR(KKK,2)=TTIME	232
	TVAR(KKK,2)=TTIME	233
C	GET BRACK ARRAY	234
	BRACK(KKK)=(XC-XXCG)*COS(ETA)/12.+(ZC*SIN(ETA))/12.	235
C	COMPUTE HYDROGEN PEROXIDE FUEL USED	236
	TVAR(KKK,8)=TVAR(1,9)-TVAR(KKK,9)	237
C	INTEGRATE MOMENTS IN PITCH AND YAW	238
	IF (KKK-1 .LE. 0) GO TO 370	239
	IF (IOPT6 .LE. 0) GO TO 360	240
	CALL TBLU (NDPR,DP,TP,DPR,MDP)	241
	CALL TBLU (NDYR,DY,TP,DYR,MDY)	242
	CALL TBLU (NDRR,DR,TP,DRR,MDR)	243
	AINI=AAIYY*DP/(57.3*BRACK(KKK))	244
	BINI=AAIYY*DY/(57.3*BRACK(KKK))	245

	CALL TBLU (NRI,CINT,TP,RI,MR)	246
	CINT=CINT+AAIXX*DR/(57.3*(RC/12.0))	247
	GO TO 370	248
C		249
360	AINT=AINT+ABS((PUAR(KKK,7)+PUAR(KKK-1,7))*(TVAR(KKK,1)-TVAR(KKK-1,1)))/(2.0*BRACK(KKK)))	250
	BINT=BINT+ABS((YUAR(KKK,7)+YUAR(KKK-1,7))*(TVAR(KKK,1)-TVAR(KKK-1,1)))/(2.0*BRACK(KKK)))	251
	CALL TBLU (NRI,CINT,TP,RI,MR)	252
	CINT=CINT+ABS(6.0*(RVAR(KKK,5)+RVAR(KKK-1,5))*(TVAR(KKK,1)-1 -TVAR(KKK-1,1))/RC)	253
	FIND TOTAL IMPULSE	254
C		255
370	TVAR(KKK,7)=AINT+BINT+CINT	256
C		257
	COMPUTE THE SPECIFIC IMPULSE	258
	IF (TVAR(KKK,8) .NE. 0) GO TO 380	259
	TVAR(KKK,6)=0.0	260
	GO TO 390	261
C		262
380	TVAR(KKK,6)=TVAR(KKK,7)/TVAR(KKK,8)	263
390	CONTINUE	264
	PUAR(KKK,3)=TTHEDD	265
	PUAR(KKK,4)=AAIYY	266
	PUAR(KKK,9)=AINT	267
	YUAR(KKK,3)=PPSIDD	268
	YUAR(KKK,4)=AAIYY	269
	YUAR(KKK,9)=BINT	270
	RVAR(KKK,3)=PPHIDD	271
	RVAR(KKK,4)=AAIXX	272
	RVAR(KKK,6)=CINT	273
	RVAR(KKK,7)=XXCG	274
	TVAR(KKK,3)=TTT	275
	IF (IT .NE. 0) GO TO 400	276
	TP=ITO	277
	IT=1	278
	GO TO 160	279
		280

C		281
400	IF (TBO-(TP+TSTEP) .LE. 0) GO TO 410	282
	TP=TP+TSTEP	283
	GO TO 160	284
C		285
410	IF (TBO-TP .LE. 0) GO TO 420	286
	TP=TBO	287
	GO TO 160	288
C		289
420	AUGISP=TUAR(KKK,6)	290
	DO 430 I=1,KKK	291
	RVAR(I,8)=TUAR(I,7)/AUGISP	292
430	RVAR(I,9)=TUAR(I,9)-RVAR(I,8)	293
	IF (IOPT5 .LE. 0) GO TO 580	294
	BOIMP=TUAR(KKK,7)	295
	WFUELM=TUAR(KKK,9)	296
	WFUELC=RVAR(KKK,9)	297
	RIC=RVAR(KKK,6)	298
	YMA=BRACK(KKK)	299
	RIXX=AAIXX	300
	YIYY=AAIYY	301
440	CONTINUE	302
	TTIME=TP-TO	303
	LLL=LLL+1	304
	CVAR(LLL,1)=TP	305
	CVAR(LLL,2)=TTIME	306
	IF (IOPT2 .GT. 0) GO TO 450	307
	CALL TBLU (NU,WUT,TP,U,MU)	308
	CVAR(LLL,9)=WUT	309
	GO TO 460	310
C		311
450	CALL TBLU (NNP,PRES,TP,P,MP)	312
	CALL TBLU (NNT,TEMP,TP,T,MT)	313
	CALL C (PRES,TEMP,CF)	314
	DU=CONST1*((P(2)*TEMP)/(CI*T(2))-PRES/CF)+CONST2*((TEMP/T(2))-1.0)	315

	CVAR(LLL,9)=WFUELI-DW	316
460	CVAR(LLL,8)=WFUELI-CVAR(LLL,9)	317
	CVAR(LLL,7)=WFUELM-CVAR(LLL,9)	318
	IF (IOPT3 .LE. 0) GO TO 470	319
	CALL TBLU (NDPR,DP,TP,DPR,MDP)	320
	CALL TBLU (NDYR,DY,TP,DYR,MDY)	321
	CALL TBLU (NDRR,DR,TP,DRR,MDR)	322
	PIMP=YIYY*DP/(57.3*YMA)	323
	YIMP=YIYY*DY/(57.3*YMA)	324
	RIMP=RIXX*DR/(57.3*(RC/12.0))	325
	CVAR(LLL,3)=PIMP+YIMP+RIMP	326
	CVAR(LLL,4)=CVAR(LLL,3)+BOIMP	327
	GO TO 480	328
C		329
470	CALL TBLU (NRI,TIMP,TP,RI,MR)	330
	CVAR(LLL,4)=BOIMP+TIMP-RIC	331
	CVAR(LLL,3)=CVAR(LLL,4)-BOIMP	332
480	IF (CVAR(LLL,7) .NE. 0.) GO TO 490	333
	CVAR(LLL,5)=0.0	334
	GO TO 500	335
C		336
490	CVAR(LLL,5)=CVAR(LLL,3)/CVAR(LLL,7)	337
500	IF (CVAR(LLL,8) .NE. 0.) GO TO 510	338
	CVAR(LLL,6)=0.0	339
	GO TO 520	340
C		341
510	CVAR(LLL,6)=CVAR(LLL,4)/CVAR(LLL,8)	342
520	IF (IC .GT. 0) GO TO 530	343
	TP=ITCO	344
	IC=1	345
	GO TO 440	346
C		347
530	IF (TCOAST-(TP+TSTEP C) .LE. 0.) GO TO 540	348
	TP=TP+TSTEP C	349
	GO TO 440	350

C	540 IF (TCOAST-TP .LE. 0.) GO TO 550	351
	TP=TCOAST	352
	GO TO 440	353
C	550 AUGISP=CUAR(LLL,5)	354
	DO 570 I=1,LLL	355
	IF (AUGISP .NE. 0.) GO TO 560	356
	CFUELC=0.0	357
	GO TO 570	358
C	560 CFUELC=CUAR(I,3)/AUGISP	359
	570 CUAR(I,10)=WFUELM-CFUELC	360
	IF (IOPTS .LT. 0) GO TO 630	361
	580 XKKK=KKK	362
	XP=XKKK/50.	363
	NP=KKK/50	364
	XNP=NP	365
	IF (XP.GT.XNP) NP=NP+1	366
	NLL=0	367
	NPP=1	368
	590 IF (NP-NPP .GT. 0) GO TO 600	369
	NFL=NLL+1	370
	NLL=KKK	371
	GO TO 610	372
C	600 NFL=NLL+1	373
	NLL=NLL+50	374
	610 WRITE(6,690) NPP	375
	WRITE(6,870) (LTITL(J),J=1,16)	376
	WRITE(6,700)	377
	WRITE(6,710) ((PUAR(I,J),J=1,9),I=NFL,NLL)	378
	WRITE(6,720) NPP	379
	WRITE(6,870) (LTITL(J),J=1,16)	380
	WRITE(6,730)	381
		382
		383
		384
		385

WRITE(6,710) ((YVAR(I,J),J=1,9),I=NFL,NLL)	386
WRITE(6,740) NPP	387
WRITE(6,870) (LTITL(J),J=1,16)	388
WRITE(6,750)	389
WRITE(6,760) ((RVAR(I,J),J=1,9),I=NFL,NLL)	390
WRITE(6,770) NPP	391
WRITE(6,870) (LTITL(J),J=1,16)	392
WRITE(6,780)	393
WRITE(6,820) ((TVAR(I,J),J=1,9),I=NFL,NLL)	394
IF (NP-NPP .LE. 0) GO TO 620	395
NPP=NPP+1	396
GO TO 590	397
C	398
620 CONTINUE	399
IF (IOPTS .LE. 0) GO TO 670	400
630 XLLL=LLL	401
XC=XLLE/50.	402
NC=LLL/50	403
XNC=NC	404
IF(XC.GT.XNC)NC=NC+1	405
NCLL=0	406
NCPP=1	407
640 IF (NC-NCPP .GT. 0) GO TO 650	408
NCFL=NCLL+1	409
NCLL=LLL	410
GO TO 660	411
C	412
650 NCFL=NCLL+1	413
NCLL=NCLL+50	414
660 WRITE(6,790) NCPP	415
WRITE(6,870) (LTITL(J),J=1,16)	416
WRITE(6,800)	417
WRITE(6,810) ((CVAR(I,J),J=1,10),I=NCFL,NCLL)	418
IF (NC-NCPP .LE. 0) GO TO 670	419
NCPP=NCPP+1	420

	GO TO 640	421
C		422
670	CONTINUE	423
	IF (IOPT4 .LE. 0) GO TO 680	424
	READ(5,860) (NTITLE(J),J=1,8)	425
	NQPL=0	426
	IF(Q(2).GT.0.)NQPL=1	427
	READ(5,840) IROLL,SFT,SFPYM,SFET,SFRM	428
	CALL CURVE (KKK,NQPL,IROLL,NTITLE,SFPYM,SFRM,SFET,SFT)	429
680	CONTINUE	430
	STOP	431
C	THIS ENDS THE UPSTAG EXECUTION. ONLY FORMAT STATEMENTS REMAIN.	432
690	FORMAT (1H1,25X,26HUPPER STAGE MOMENT ROUTINE,14X,6HPAGE =,I2,2H A	433
	1/25X,31H PITCH VARIABLES TIME HISTORIES)	434
700	FORMAT (//4X,6HFLIGHT,2X,5HSTAGE,2X,7HANGULAR,2X,6HMOMENT,4X,4HAER	435
	10,3X,8HMISALIGN,3X,5HTOTAL,3X,6HTHRUST/2(4X,4HTIME),4X,5HACCEL,2X,	436
	28HOF INER.,2X,3(6HMOMENT,3X),6HMISALN,1X,7HIMPULSE/5X,3HSEC,5X,3HS	437
	3EC,3X,7HDEG/S/S,1X,8HSLUG-FT2,3X,3(5HFT-LB,4X),3HDEG,4X,6HLB-SEC//	438
	4)	439
710	FORMAT (3X,F7.2,1X,F6.2,2X,F6.2,2X,F8.1,1X,F8.2,1X,F8.2,1X,F8.2,1X	440
	1,F7.4,1X,F7.2)	441
720	FORMAT (1H1,25X,26HUPPER STAGE MOMENT ROUTINE,14X,6HPAGE =,I2,2H B	442
	1/25X,31H YAW VARIABLES TIME HISTORIES)	443
730	FORMAT (//4X,6HFLIGHT,2X,5HSTAGE,2X,7HANGULAR,2X,6HMOMENT,4X,4HAER	444
	10,3X,8HMISALIGN,3X,5HTOTAL,3X,6HTHRUST/2(4X,4HTIME),4X,5HACCEL,2X,	445
	28HOF INER.,2X,3(6HMOMENT,3X),6HMISALN,1X,7HIMPULSE/5X,3HSEC,5X,3HS	446
	3EC,3X,7HDEG/S/S,1X,8HSLUG-FT2,3X,3(5HFT-LB,4X),3HDEG,4X,6HLB-SEC//	447
	4)	448
740	FORMAT (1H1,25X,26HUPPER STAGE MOMENT ROUTINE,14X,6HPAGE =,I2,2H C	449
	1/25X,31H ROLL VARIABLES TIME HISTORIES)	450
750	FORMAT (//4X,6HFLIGHT,2X,5HSTAGE,2X,7HANGULAR,1X,6HMOMENT,4X,5HTOT	451
	1AL,13X,4HC.G.,4X,18H CALCULATED FUEL /2(4X,4HTIME),4X,5HACCEL,2X,	452
	27HOF INER,3X,6HMOMENT,2X,7HIMPULSE,3X,5HPOINT,3X,7H CONSUM,3X,7HRE	453
	3MAIN /5X,3HSEC,5X,3HSEC,3X,7HDEG/S/S,1X,8HSLUG-FT2,2X,5HFT-LB,3X,6	454
	4HLB-SEC,4X,4HINCH,7X,2HLB,7X,2HLB//)	455

760	FORMAT (3X,F7.2,1X,F6.2,2X,F6.2,2X,F8.1,1X,F8.2,1X,F7.2,1X,F8.3,1X	456
	1,F8.3,1X,F8.3)	457
770	FORMAT (1H1,25X,26HUPPER STAGE MOMENT ROUTINE,14X,6HPAGE -,I2,2H D	458
	1/25X,31H TIME HISTORIES OF SYSTEM)	459
780	FORMAT (//4X,6HFLIGHT,2X,5HSTAGE,11X,5HTOTAL,10X,8HSPECIFIC,2X,5HT	460
	10TAL,2(4X,4HFUEL)/2(4X,4HTIME),3X,6HTHRUST,2X,7HMISALGN,2X,5HLAMDA	461
	2,2X,2(7HIMPULSE,2X),6HCONSUM,2X,6HREMAIN/5X,3HSEC,5X,3HSEC,5X,2HLB	462
	3,6X,3HDEG,5X,3HDEG,5X,3HSEC,4X,6HLB-SEC,4X,2HLB,6X,2HLB//)	463
790	FORMAT (1H1,25X,26HUPPER STAGE MOMENT ROUTINE,14X,6HPAGE -,I2,2H E	464
	1/25X,31H COAST VARIABLES TIME HISTORIES)	465
800	FORMAT (//,4X,6HFLIGHT,2X,5HSTAGE,3X,5HCOAST,3X,5HTOTAL,2X,5HCOAST	466
	1,,2X,5HTOTAL,3X,5HCOAST,3X,5HTOTAL,2X,14HFUEL REMAINING,/5X,4HTIME	467
	2,3X,4HTIME,3X,2(7HIMPULSE,1X),1X,2(3HISP,4X),4HFUEL,4X,4HFUEL,3X,1	468
	34H MEAS CALC /5X,3HSEC,5X,3HSEC,3X,2(6HLB-SEC,2X),1X,2(3HSEC,4X	469
	4),2HLB,7X,2HLB,6X,2HLB,6X,2HLB//)	470
810	FORMAT (3X,F7.2,1X,F6.2,1X,F7.1,1X,F7.1,1X,F6.2,1X,F6.2,1X,F7.2,1X	471
	1,F7.2,1X,F7.2,1X,F7.2)	472
820	FORMAT (3X,F7.2,1X,F6.2,2X,F7.0,1X,F7.4,1X,F7.2,1X,F7.2,1X,F8.2,1X	473
	1,F6.2,2X,F7.2)	474
830	FORMAT (10I5)	475
840	FORMAT (I5/(6E10.3))	476
850	FORMAT (6E10.3)	477
860	FORMAT (8A10)	478
870	FORMAT (1X,8A10)	479
880	FORMAT (I5/(7E10.3))	480
	END	481

*DECK C		1
SUBROUTINE C (PAT,TAT,CAT)		2
C THIS SUBROUTINE COMPUTES THE COMPRESSIBILITY FACTOR FOR DRY		3
C NITROGEN FOR 50-100 DEG F. AND 400-3000 PSIA		4
PP=PAT-1400.		5
CAT=.9977+1.657738E-5*PP+1.264881E-8*PP*PP+4.5833E-4*(TAT-522.)		6
RETURN		7
END		8
*DECK CURVE		1
SUBROUTINE CURVE (NP,NQ,IROLL,NTITLE,DY,DYR,DYET,DX)		2
C THIS SUBROUTINE PERFORMS THE CALCOMP PLOT SETUP FOR PITCH, YAW		3
C AND ROLL MOMENTS AND THRUST MISALIGNMENT.		4
DIMENSION NTITLE(8),X(400),Y(400)		5
COMMON PVAR(200,9),YVAR(200,9),RVAR(200,9),TVAR(200,9)		6
DATA Z1,Z2,Z3/0.42,0.07,0.14/		7
C SET UP INITIAL AXIS VARIABLES		8
C		9
YF=-2.*DY		10
NDX=DX		11
CALL PLOTS (5HCAL19,0,4HPLOT)		12
DO 10 J=1,NP		13
10 X(J)=PVAR(J,1)		14
C PLOT PITCH MOMENTS		15
CALL SYMBOL (0.5,9.9,0.10,NTITLE,0.,80)		16
CALL SYMBOL (0.5,9.5,0.10,45H	PITCH AND YAW DISTURBING	17
1 MOMENTS,0.,45)		18
CALL SYMBOL(3.5,9.3,0.07,12HTOTAL MOMENT,0.,12)		19
CALL PLOT(3.4,9.3,3)		20
CALL PLOT(2.4,9.3,2)		21
CALL PLOT(2.4,9.15,3)		22
CALL PLOT(2.6,9.15,2)		23
CALL PLOT(2.7,9.15,3)		24
CALL PLOT(2.9,9.15,2)		25

CALL PLOT(3.0,9.15,3)	26
CALL PLOT(3.2,9.15,2)	27
CALL PLOT(3.3,9.15,3)	28
CALL PLOT(3.4,9.15,2)	29
CALL SYMBOL(3.5,9.15,0.07,26HTHRUST MISALIGNMENT MOMENT ,0.,26)	30
CALL PLOT(2.4,9.0,3)	31
CALL PLOT(2.8,9.0,2)	32
CALL PLOT(2.90,9.0,3)	33
CALL PLOT(2.95,9.0,2)	34
CALL PLOT(3.05,9.0,3)	35
CALL PLOT(3.4,9.0,2)	36
CALL SYMBOL(3.5,9.0,0.07,18HAERODYNAMIC MOMENT ,0.,18)	37
NTI=X(1)/DX	38
XF=NTI*NDX	39
CALL PLOT (1.,7.,-3)	40
CALL AXIS (0.,-2.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	41
DO 20 J=1,NP	42
X(J)=(X(J)-XF)/DX	43
20 Y(J)=PUAR(J,7)	44
CALL AXIS (0.,-2.,19HPITCH MOMENT FT-LBS,19,4.,90.,YF,DY)	45
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DY,0,7.,3.)	46
IF (NQ.EQ.0) GO TO 50	47
DO 30 J=1,NP	48
30 Y(J)=PUAR(J,6)	49
CALL DASH (X,Y,NP,Z3,Z3,Z2,1.,DY,0,7.,3.)	50
DO 40 J=1,NP	51
40 Y(J)=PUAR(J,5)	52
CALL DASH (X,Y,NP,Z1,Z2,Z3,1.,DY,0,7.,3.)	53
C PLOT YAW MOMENTS	54
50 CALL PLOT (0.,-5.,-3)	55
CALL AXIS (0.,-2.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	56
CALL AXIS (0.,-2.,17HYAW MOMENT FT-LBS,17,4.,90.,YF,DY)	57
DO 60 J=1,NP	58
60 Y(J)=YVAR(J,7)	59
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DY,0,7.,3.)	60

IF (NQ.EQ.0) GO TO 90	61
DO 70 J=1,NP	62
70 Y(J)=YUAR(J,6)	63
CALL DASH (X,Y,NP,Z3,Z3,Z2,1.,DY,0,7.,3.)	64
DO 80 J=1,NP	65
80 Y(J)=YUAR(J,5)	66
CALL DASH (X,Y,NP,Z1,Z2,Z3,1.,DY,0,7.,3.)	67
90 CALL PLOT (-1.,-2.,-3)	68
CALL PLOT (12.,0.,-3)	69
CALL PLOT (0.,0.,999)	70
C CHECK AND PLOT ROLL MOMENTS	71
IF (IROLL.EQ.0) GO TO 110	72
YFR=-4.*DYR	73
CALL PLOTS (5HCAL19,0,4HPLOT)	74
CALL SYMBOL (1.,9.8,0.10,NTITLE,0.,80)	75
CALL SYMBOL (1.,9.5,0.10,35H	76
1,35)	77
CALL PLOT (1.,5.,-3)	78
CALL AXIS (0.,-4.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	79
CALL AXIS (0.,-4.,29HROLL DISTURBING MOMENT FT-LBS,29,8.,90.,YFR,D	80
1YR)	81
DO 100 J=1,NP	82
100 Y(J)=RUAR(J,5)	83
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DYR,0,7.,5.)	84
CALL PLOT (11.,-5.,-3)	85
CALL PLOT (0.,0.,999)	86
C PLOT THRUST MISALIGNMENTS	87
110 CALL PLOTS (5HCAL19,0,4HPLOT)	88
YFET=-DYET	89
CALL SYMBOL (1.,9.8,0.10,NTITLE,0.,80)	90
CALL SYMBOL (1.,9.5,0.10,32H	91
1)	92
CALL PLOT (1.,7.,-3)	93
CALL AXIS (0.,-1.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	94
CALL AXIS (0.,-1.,19HPITCH COMPONENT DEG,19,3.,90.,YFET,DYET)	95

DO 120 J=1,NP	96
120 Y(J)=PUAR(J,8)	97
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DYET,0,7.,3.)	98
CALL PLOT (0.,-3.,-3)	99
CALL AXIS (0.,-1.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	100
CALL AXIS (0.,-1.,17HYAW COMPONENT DEG,17,2.,90.,YFET,DYET)	101
DO 130 J=1,NP	102
130 Y(J)=YUAR(J,8)	103
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DYET,0,7.,3.)	104
CALL PLOT (0.,-4.,-3)	105
CALL AXIS (0.,0.,20HFLIGHT TIME SECONDS ,-20,6.,0.,XF,DX)	106
CALL AXIS (0.,0.,9HTOTAL DEG,9,2.,90.,0.,DYET)	107
DO 140 J=1,NP	108
140 Y(J)=TVAR(J,4)	109
CALL DASH (X,Y,NP,Z1,Z1,0.,1.,DYET,0,7.,3.)	110
CALL PLOT (11.,0.,-3)	111
CALL PLOT (0.,0.,999)	112
RETURN	113
END	114

*DECK	DASH	1
	SUBROUTINE DASH (X,Y,NP,Z1,Z2,SPACE,XSCALE,YSCALE,LSYMB,XLIM,YLIM)	2
C	SYMBOLS,DASHED,DASHED-DOT LINES OR SOLID LINES WITH OR WITHOUT	3
C	SYMBOLS BASED ON A SET OF SEQUENTIAL POINTS GIVEN IN	4
C	THE INPUT 'X' ABSCISSA ARRAY AND THE 'Y' ORDINATE ARRAY	5
	DIMENSION X(1),Y(1)	6
	DO 10 I=1,NP	7
	XA=X(I)/XSCALE	8
	YA=Y(I)/YSCALE	9
	IF (ABS(XA).GT.XLIM) GO TO 10	10
	IF (ABS(YA).GT.YLIM) GO TO 10	11
	CALL PLOT (XA,YA,3)	12
	GO TO 20	13
10	CONTINUE	14
20	IF (SPACE) 330,310,30	15
C	THIS SUBROUTINE PLOTS A CALCOMP PLOT WITH A WIDE VARIETY OF	16
30	K=0	17
	PI2=1.5708	18
	Z=Z1	19
	ZB=Z2	20
	IF (Z2 .GT. 0.) GO TO 40	21
	ZB=Z1	22
40	ZD=Z	23
	LZ=0	24
	SL=0.	25
	NF=NP-1	26
	DO 300 J=1,NF	27
	XA=X(J)/XSCALE	28
	IF (ABS(XA)-XLIM .GT. 0.) GO TO 300	29
	XB=X(J+1)/XSCALE	30
	IF (ABS(XB)-XLIM .GT. 0.) GO TO 300	31
	YA=Y(J)/YSCALE	32
	IF (ABS(YA)-YLIM .GT. 0.) GO TO 300	33
	YB=Y(J+1)/YSCALE	34
	IF (ABS(YB)-YLIM .GT. 0.) GO TO 300	35

DY=YB-YA	36
DX=XB-XA	37
IF (DX .NE. 0.) GO TO 80	38
IF (DY) 50,60,70	39
50 TH=-PI2	40
GO TO 90	41
60 TH=0.	42
GO TO 90	43
70 TH=PI2	44
GO TO 90	45
80 TH=ATAN(DY/DX)	46
90 DX=XB-XA	47
DY=YB-YA	48
DZ=SQRT(DX*DX+DY*DY)	49
C TEST TO SEE WHAT IS GOING ON	50
IF (K) 100,180,220	51
100 K=1	52
SL=SPACE	53
IF (DZ-SPACE) 110,120,150	54
C SPACE IS LARGER THAN DZ	55
110 SL=SL-DZ	56
CALL PLOT (XB,YB,3)	57
GO TO 300	58
C NEXT POINT IS EXACTLY ONE SPACE	59
120 K=0	60
IF (LZ .NE. 0) GO TO 130	61
ZD=ZB	62
LZ=1	63
GO TO 140	64
130 ZD=Z	65
LZ=0	66
140 SL=0.	67
CALL PLOT (XB,YB,3)	68
GO TO 300	69
C NEXT POINT MORE THAN ONE SPACE AWAY	70

150	XA=XA+SPACE*COS(TH)	71
	YA=YA+SPACE*SIN(TH)	72
	IF (ABS(XA)-XLIM .GE. 0.) GO TO 300	73
	IF (ABS(YA)-YLIM .GE. 0.) GO TO 300	74
	K=0	75
	IF (LZ .NE. 0) GO TO 160	76
	ZD=ZB	77
	LZ=1	78
	GO TO 170	79
160	ZD=Z	80
	LZ=0	81
170	SL=0.	82
	CALL PLOT (XA,YA,3)	83
	GO TO 90	84
C	K=0 LINE BEING DRAWN ZD LENGTH NOT DRAWN RESUME AS IS LINE STARTING	85
180	IF (DZ-ZD) 190,200,210	86
C	LINE GOES AT LEAST TO NEXT POINT	87
190	K=0	88
	ZD=ZD-DZ	89
	CALL PLOT (XB,YB,2)	90
	GO TO 300	91
C	LINE ENDS AT NEXT POINT	92
200	K=-1	93
	SL=SPACE	94
	ZD=0.	95
	CALL PLOT (XB,YB,2)	96
	GO TO 300	97
C	LINE ENDS BEFORE NEXT POINT	98
210	K=1	99
	SL=SPACE	100
	XA=XA+ZD*COS(TH)	101
	YA=YA+ZD*SIN(TH)	102
	IF (ABS(XA)-XLIM .GE. 0.) GO TO 300	103
	IF (ABS(YA)-YLIM .GE. 0.) GO TO 300	104
	CALL PLOT (XA,YA,2)	105

	ZD=0.	106
	GO TO 90	107
C	K=1 IS IN SPACE	108
220	ZD=0.	109
	IF (DZ-SL) 230,240,270	110
230	K=1	111
	SL=SL-DZ	112
	CALL PLOT (XB,YB,3)	113
	GO TO 300	114
C	SL=DZ	115
240	K=0	116
	IF (LZ .NE. 0) GO TO 250	117
	ZD=ZB	118
	LZ=1	119
	GO TO 260	120
250	ZD=Z	121
	LZ=0	122
260	CALL PLOT (XB,YB,3)	123
	GO TO 300	124
C	SL IS LESS THAN DZ	125
270	K=0	126
	IF (LZ .NE. 0) GO TO 280	127
	ZD=ZB	128
	LZ=1	129
	GO TO 290	130
280	ZD=Z	131
	LZ=0	132
290	XA=XA+SL*COS(TH)	133
	YA=YA+SL*SIN(TH)	134
	IF (ABS(XA)-XLIM .GE. 0.) GO TO 300	135
	IF (ABS(YA)-YLIM .GE. 0.) GO TO 300	136
	SL=0.	137
	CALL PLOT (XA,YA,3)	138
	GO TO 90	139
300	CONTINUE	140

GO TO 370	141
C STRAIGHT LINE PLOT OPTION	142
310 DO 320 J=1,NP	143
XA=X(J)/XSCALE	144
YA=Y(J)/YSCALE	145
IF (ABS(XA)-XLIM .GT. 0.) GO TO 320	146
IF (ABS(YA)-YLIM .GT. 0.) GO TO 320	147
CALL PLOT (XA,YA,2)	148
320 CONTINUE	149
GO TO 370	150
C PLOT SYMBOLS ON LINE NO LINE IF LYSMB IS NEGATIVE	151
330 NSM=IABS(LSYMB)	152
IF (LSYMB .LT. 0) GO TO 340	153
K=-2	154
GO TO 350	155
340 K=-1	156
350 DO 360 J=1,NP	157
XA=X(J)/XSCALE	158
YA=Y(J)/YSCALE	159
IF (ABS(XA)-XLIM .GT. 0.) GO TO 360	160
IF (ABS(YA)-YLIM .GT. 0.) GO TO 360	161
CALL SYMBOL (XA,YA,0.07,NSM,0.0,K)	162
360 CONTINUE	163
370 CALL PLOT (0.,0.,3)	164
RETURN	165
END	166

*DECK	TBLU	1
	SUBROUTINE TBLU (NT,Y,X,T,M)	2
C	SINGLE TABLE LOOKUP SUBROUTINE	3
C	NT = NUMBER OF VALUES IN ARRAY	4
C	Y = RETURNED ORDINATE	5
C	X = ABSCISSA VALUE CALLED	6
C	T = INPUT TABLE OF ALTERNATING ABSCISSAS AND ORDINATES	7
C	ORDINATES MUST BE MONOTONICALLY INCREASING	8
C	M = PREVIOUS INDEX USED IN THIS TABLE LOOKUP	9
C	THIS INDEX GETS CHANGED TO CURRENT VALUE	10
	DIMENSION T(1)	11
10	IF (T(M)-X) 50,20,30	12
20	Y=T(M+1)	13
	RETURN	14
30	IF (T(1)-X.LT.0.) GO TO 40	15
	M=1	16
	GO TO 20	17
40	M=M-2	18
	GO TO 10	19
50	MM=M+2	20
	IF (MM-NT-1.LE.0) GO TO 60	21
	M=NT-1	22
	GO TO 20	23
60	IF (T(MM)-X.GT.0.) GO TO 70	24
	M=MM	25
	GO TO 50	26
70	M=MM-2	27
	DT=T(MM)-T(M)	28
	IF (DT.NE.0.) GO TO 80	29
	Y=T(M+1)	30
	RETURN	31
80	DY=T(MM+1)-T(M+1)	32
	DDT=X-T(M)	33
	Y=T(M+1)+DY*DDT/DT	34
	RETURN	35
	END	36

1 Report No NASA CR-166029		2 Government Accession No		3 Recipient's Catalog No	
4 Title and Subtitle COMPUTER PROGRAM FOR POST-FLIGHT EVALUATION OF A LAUNCH VEHICLE UPPER-STAGE ON-OFF REACTION CONTROL SYSTEM				5 Report Date November 1982	
				6 Performing Organization Code	
7 Author(s) R. N. KNAUBER				8 Performing Organization Report No	
				10 Work Unit No	
9 Performing Organization Name and Address VOUGHT CORPORATION P.O. Box 225907 DALLAS, TX 75265				11 Contract or Grant No NAS1-15000	
				13 Type of Report and Period Covered Contractor Report	
12 Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546				14 Sponsoring Agency Code 490-02-02-77-00	
15 Supplementary Notes Langley Technical Monitor: Robert J. Keynton					
16 Abstract This report describes a FORTRAN IV coded computer program for post-flight evaluation of a launch vehicle upper stage ON-OFF reaction control system. Aerodynamic and thrust misalignment disturbances are computed as well as the total disturbing moments in pitch, yaw, and roll. Effective thrust misalignment angle time histories of the rocket booster motor are calculated. Disturbing moments are integrated and used to estimate the required control system total impulse. Effective control system specific impulse is computed for the boost and coast phases using measured control fuel usage. This method has been used for more than fifteen years for analyzing the NASA Scout Launch Vehicle second and third-stage reaction control system performance. The computer program is set up in FORTRAN IV for a CDC CYBER 175 system. With slight modification it can be used on other machines having a FORTRAN compiler. The program has optional CALCOMP plotting output. With this option the program requires 19K words of memory and has 786 cards. Running time on a CDC CYBER 175 system is less than three (3) seconds for a typical problem.					
17 Key Words (Suggested by Author(s)) COMPUTER PROGRAM, POST-FLIGHT ANALYSIS, ON-OFF REACTION CONTROLS, RIGID BODY MOMENTS			18 Distribution Statement FOUO Distribution Subject Category 61		
19 Security Classif (of this report) UNCLASSIFIED	20 Security Classif (of this page) UNCLASSIFIED	21 No of Pages 78	22 Price		

Available: NASA's Industrial Applications Centers

End of Document